G. M. Darrow

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

FOR

# HORTICULTURAL SCIENCE



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H. B. Tukey, Editor and Business Manager
Michigan State College,
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# CONSTITUTION*

## ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

## ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

## ARTICLE III

*Voting members:* Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

*Associate Members:* Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

## ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

## ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

## ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

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*As revised and adopted at the Boston meeting, December 29, 1946.

# BY-LAWS

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and

distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be six dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers as chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of six dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers:* The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

# SOUTHERN REGION

The eleventh annual meeting of the Southern Region was held in conjunction with the forty-sixth annual convention of the Association of Southern Agricultural Workers at Louisiana State University on January 31, February 1 and 2. The program consisted of two work conferences, four roundtable discussions, four sessions on general papers, a joint session with the Section of Plant Physiology on Chemical Control of Weeds with Dr. J. B. Edmond as chairman, a special program on Organic Insecticides and their Effect on the Flavor of Peaches with Dr. J. H. Weinberger as chairman, and two all-section programs, one on Pre-packaging of Horticultural Products with Mr. Harold A. Schomer as chairman, and one other on Problems on Resident Teaching and Extension with Dr. F. S. Andrews as chairman. All sessions were well attended, the members were pleased with the facilities provided, and a total of 56 papers were presented.

The banquet and social evening at which over 110 were present was held at the Faculty Club on the University campus with Dr. J. C. Miller as toastmaster. Distinguished guests were: Dr. T. H. McHatton, Dr. V. R. Boswell, Dr. G. F. Potter, past presidents, and Dr. F. S. Howlett, Secretary-Treasurer of the Society. A feature of the evening was the presentation of the address of the retiring chairman, "Balanced Programs for Southern Horticulture".

At the business meeting the Region authorized the creation of Sectional Chairman, one for each of the four sections, Pomology, Vegetable Crops, Floriculture and Ornamental Horticulture, and Processing. Dr. S. H. Yarnell was re-elected to serve as General Chairman of the Southern Vegetable Variety Trials. The group as a whole was highly in favor of meeting again on a university or college campus.

The following officers were elected for 1949–50: *Chairman,* J. H. Weinberger; *Vice-Chairman,* F. F. Cowart; *Secretary-Treasurer,* J. B. Edmond; and *Sectional Chairmen,* W. T. Brightwell (Pomology), F. D. Cochran (Vegetable Crops), E. W. McElwee (Floriculture and Ornamental Horticulture), and L. O. Van Blaricom (Processing).

## SUMMARY OF INCOME AND EXPENSES
## FOR YEAR ENDING DECEMBER 31, 1948

*Cash Balances*

| | | | |
|---|---|---|---|
| Wayne Co. National Bank — December 31, 1947 | | $ 2,909.08 | |
| Lincoln Rochester Trust Co. — December 31, 1947 | | 10,611.75 | |
| Total Starting Funds | | | $13,520.83 |

*Receipts*

| | | | |
|---|---|---|---|
| Membership dues collected | $8,666.50 | | |
| *Less* — Refunds on literature | 197.90 | $8,468.60 | |
| Money order returned by Tukey | | 5.00 | |
| Banquet tickets | | 128.00 | |
| Refund on room rent | | 6.25 | |
| Insurance claim on lost volume | | 6.15 | |
| Leonard H. Vaughn Memorial Award | | 1,000.00 | |
| Deposits made by W. F. Humphrey Press, Inc. | | 9,962.40 | |
| Total Receipts | | | 19,576.40 |
| Total Funds to be Accounted for | | | $33,097.23 |

*Disbursements*

| | | |
|---|---|---|
| Printing and engraving | $13,771.25 | |
| Office supplies and expenses | 650.08 | |
| Expense of secretary to Howlett | 651.63 | |
| Expense of secretary to Tukey | 290 80 | |
| Bond | 29 25 | |
| Bank charges | 10.91 | |
| Collection charges | 3 24 | |
| Returned checks charged to bank account | 156 20 | |
| Telephone & telegraph | 39.03 | |
| Travel expense — Howlett | 244.19 | |
| Commissions to W. F. Humphrey Press, Inc. | 1,968.98 | |
| Legal expense | 100.88 | |
| Annual meeting expense — December 31, 1947 | 459.52 | |
| Annual meeting expense — August 10, 1948 | 174.76 | |
| Postage and express on manuscripts, reprints | 819 55 | |
| Rental on projector | 15.00 | |
| Leonard H. Vaughn Memorial Award | 1,000.00 | |
| Dues to American Institute of Biological Science | 1,270.50 | |
| Total Disbursements | | 21,655 97 |
| Balance of Funds | | $11,441.26 |

*Cash Balances — December 31, 1948*

| | | |
|---|---|---|
| Wayne Co. National Bank | $3,487.05 | |
| Lincoln Rochester Trust Co. | 7,954.21 | |
| TOTAL FUNDS | | $11,441 26 |

I have completed an audit of the books of the American Society for Horticultural Science for the period January 1, 1948 to December 31, 1948.

Receipts for dues have been checked against membership records and are found to be deposited to the checking account of the Society. Deposits by the W. F. Humphrey Press, Inc., are accepted as listed since no records are available for verification. However, the Society does receive periodic reports from Robert H. Breslin, C.P.A., Geneva, N. Y., covering the transactions made by the W. F. Humphrey Press, Inc., for your account.

Disbursements were verified against cancelled checks. The present cash balances in the depository banks were verified by inspection of statements furnished. The funds in the banks after allowance for outstanding checks are in agreement with society records.

I hereby, certify that to the best of my knowledge all funds of the society have been properly accounted for and the records of the association are in accord with the opening and closing cash balances.

Respectfully submitted,
HAROLD R. GERBERICH, C.P.A. (Ohio)

# A Study of Correlation Between Growth and Certain Nutrient Reserves in Young Apple Trees

By C. P. Harley, H. H. Moon, and L. O. Regeimbal,
*Plant Industry Station, Beltsville, Md.*

A relationship between early spring growth and the concentration of reserve nutrients in branches and twigs of the apple, and other deciduous fruit trees, is generally recognized. Suggestive as to the role of nutrient reserves are the analyses for carbohydrate and nitrogen fractions of bark and wood that show a partial depletion of the reserve substances in the older tisues at the time of growth initiation. Roberts (2) in 1921 observed "that apple trees which were previously poorly vegetative made little growth when maintained in a low nitrogen nutrient........while trees which were previously very vegetative made an excellent growth after being transferred to a low nitrogen nutrient". More recently, Edgerton (1) found that potassium stored in the trunk, stock, and root system, the first season under high potassium treatments, was sufficient to promote fair growth of shoots the second season when these trees were supplied with minus-potassium solutions.

The purpose of the present study was to determine the effect of three levels of nitrogen, potassium, and magnesium, as measured by the new growth produced in the following year. No nutrients were given the second year.

## Procedure in 1947

One hundred and thirty-five selected 1-year-old Stayman Winesap apple trees were cut back to one bud and grown in pots in pure quartz sand, in the greenhouse from April 9 to December 11. The experimental plan consisted of 27 factorial combinations of three levels of N, K, and Mg, with five trees per treatment as replicates. Ca, P, B, Zn, and Mn were supplied in all treatments. The concentrations employed were the following:

$N_1$ 10 ppm; $N_2$ 50 ppm; $N_3$ 150 ppm; $K_1$ 3 ppm; $K_2$ 40 ppm; $K_3$ 120 ppm; $Mg_1$ 2 ppm; $Mg_2$ 20 ppm; $Mg_3$ 100 ppm; Ca 100 ppm; P 10 ppm; B .12 ppm; Zn .25 ppm; and Mn .25 ppm.

Nutrient solutions were added every other day during the greater part of the growth period. On the intervening days the sand was flushed with distilled water.

At the approach of dormancy, as indicated by complete defoliation, the trees were removed from the greenhouse and placed in a storage room where temperatures of 32 to 38 degrees F prevailed.

A more detailed description of the 1947 procedure will be given in a later report.

## Procedure in 1948

The trees were removed from cold storage without disturbing the root systems and returned to the greenhouse on March 1. The previous year's trunk growth was cut back to 60 cm, and the sand and roots were leached thoroughly with distilled water. No nutri-

ents were added to the sand at any time in 1948. Thus growth was initiated and maintained on reserve nutrients of the trunk, stock, and root system. Since the sand was quite course it is assumed that ion adsorption from 1947 treatments was negligible or non-existent following the numerous flushings with distilled water. All buds on the trunk were permitted to develop, and growth was considered as completed when terminal buds were formed and leaves were fully expanded on all shoots.

Beginning May 19, when all growth was completed, the trees were harvested and each tree divided into three parts, representing (a) new growth, including leaves and shoots; (b) old tops, consisting of trunk and stock above the level of sand; and (c) root system, original roots plus growth made in 1947 and 1948. These samples were dried in a forced-draft oven at 80 degrees C and weighed for dry matter content.

## Results

In 1947 a deficiency of nitrogen was evident in the early growth of all $N_1$ treatments, and this condition continued throughout the growth period. Magnesium deficiency symptoms were severe on basal leaves of all $Mg_1K_3$ plots and prevalent on certain $Mg_2K_3$ plots. Severe magnesium deficiency was always accompanied by falling of the affected leaves. No visual potassium deficiency was evident on leaves at any time, even in those trees grown with only 3 ppm K. The total trunk growth in height and caliper at the end of the 1947 period is given in Table I, and is a true index of response, for no lateral shoots were permitted to develop.

TABLE I—Effect of a Three-Level Interrelationship of Nitrogen, Potassium, and Magnesium on the Growth of Young Stayman Winesap Apple Trees, When Grown With Sand Culture in 1947; and the Correlation Between Growth Made by the Same Trees in 1948 and the Dry Weights of Old Tops and Roots, When Grown in Sand with Distilled Water Only.

| Nutrient Levels and Designations | Average Growth of Trees in Nutrient Culture (1947) | | Average Dry Weights for Components of Trees Grown With Distilled Water (1948) | | |
|---|---|---|---|---|---|
| | Diameter of Trunk at the 5th Internode (Mm) | Total Top Length (Cm) | New Growth (Gm) | Old Tops (Gm) | Roots (Gm) |
| | | | *Nitrogen* | | |
| $N_1$ 10 ppm | 8.0 | 143.1 | 12.5 | 37.5 | 47.2 |
| $N_2$ 50 ppm | 10.7 | 170.4 | 27 0 | 54.2 | 65.2 |
| $N_3$ 150 ppm | 11.1 | 175.1 | 30.6 | 57.3 | 66.2 |
| | | | *Potassium* | | |
| $K_1$ 3 ppm | 8.8 | 147.0 | 20.2 | 43.6 | 57.1 |
| $K_2$ 40 ppm | 10.4 | 169.9 | 24.1 | 51.5 | 61.8 |
| $K_3$ 120 ppm | 10.6 | 171.7 | 25.8 | 53.9 | 59.7 |
| | | | *Magnesium* | | |
| $Mg_1$ 2 ppm | 9.4 | 154.8 | 19.7 | 45.1 | 51.5 |
| $Mg_2$ 20 ppm | 10.2 | 166.7 | 24.8 | 51.4 | 61.5 |
| $Mg_3$ 100 ppm | 10.2 | 167.1 | 25.6 | 52.5 | 65.6 |
| Differences required for significance at 0.05 | 0.37 | 3.49 | Correlation Cofficients for dry weights between:<br>New growth and old tops .............. .899<br>New growth and roots ............... .748<br>Required for significance at 0.01 ........ .228 | | |

Growth made by the same trees in 1948, then receiving only distilled water, is also shown in Table I. Since a large portion of the 1947 growth was removed the new growth values for 1948 are probably not strictly comparable with the growth made in 1947; however, relationships between new growth in 1948 and top and root dry weights are valid and highly significant. Without considering the influence of nutrient levels in the sand culture there is a strong positive correlation between the new growth and the reserves stored in the trunk, the stock, and the root system as measured by dry matter in all tissues at the end of the experiment. The data here refer primarily to gross reserve rather than specific elements although there is evidence of influence of different levels of all three elements, especially of nitrogen.

Fig 1 illustrates the type of growth made by the experimental trees in 1948 with only distilled water. The tree on the left is typical of those in the $N_1$ series, having a relatively low nitrogen reserve. The middle tree is from the $N_2$ treatments and is representative of trees having an intermediate nitrogen reserve. The tree on the right is from the $N_3$ treatments and shows growth resulting from a high reserve of nitrogen.

A more detailed evaluation of the effect of the 3-element factorial

FIG. 1. Types of growth made in 1948 by Stayman Winesap apple trees in pure quartz sand and distilled water. These same trees received nutrients in 1947 and belonged, from left to right, to the series $N_1$ $K_3$ $Mg_3$ and $N_2$ $K_3$ $Mg_3$, and $N_3$ $K_3$ $Mg_3$, respectively.

combination on growth resulting from reserves of these elements is shown in Table II. The observed values of F plainly indicate the influence of all three elements, both in the primary actions and in the interactions. As would be expected, the greatest effect is shown by nitrogen and no significant growth response to varying amounts of either potassium or magnesium occurred when nitrogen was the

TABLE II—RELATIONSHIP BETWEEN A THREE-ELEMENT FACTORIAL COMBINATION IN NUTRIENT CULTURE IN 1947 AND THE AMOUNT OF NEW GROWTH PRODUCED BY YOUNG STAYMAN WINESAP APPLE TREES REDUCED TO 60 CM IN HEIGHT THE FOLLOWING YEAR WHEN GROWN WITH DISTILLED WATER ALONE

| Nutrient Level Designations (1947) | Average Dry Weights (Gm) of New Growth (1948) | Nutrient Level Designations (1947) | Average Dry Weights (Gm) of New Growth (1948) | Nutrient Level Designations (1947) | Average Dry Weights (Gm) of New Growth (1948) | Primary Actions and Interactions | F Found | F Required for Significance at 0.01 Level |
|---|---|---|---|---|---|---|---|---|
| $N_1K_1Mg_1$ | 13.4 | $N_2K_1Mg_1$ | 19.8 | $N_3K_1Mg_1$ | 23.8 | | | |
| $N_1K_1Mg_2$ | 12.8 | $N_2K_1Mg_2$ | 21.6 | $N_3K_1Mg_2$ | 26 8 | N | 250.3 | |
| $N_1K_1Mg_3$ | 13.5 | $N_2K_1Mg_3$ | 24.2 | $N_3K_1Mg_3$ | 26.4 | K | 22.5 | 4.82 |
| $N_1K_2Mg_1$ | 12.7 | $N_2K_2Mg_1$ | 23.5 | $N_3K_2Mg_1$ | 22.7 | Mg | 29.0 | |
| $N_1K_2Mg_2$ | 10.1 | $N_2K_2Mg_2$ | 30.2 | $N_3K_2Mg_2$ | 35.4 | | | |
| $N_1K_2Mg_3$ | 14.3 | $N_2K_2Mg_3$ | 33.6 | $N_3K_2Mg_3$ | 34.1 | N×K | 8.83 | |
| $N_1K_3Mg_1$ | 10.3 | $N_2K_3Mg_1$ | 21.7 | $N_3K_3Mg_1$ | 29.1 | N×Mg | 6 01 | 3.51 |
| $N_1K_3Mg_2$ | 12.5 | $N_2K_3Mg_2$ | 35.3 | $N_3K_3Mg_2$ | 39 1 | K×Mg | 3.81 | |
| $N_1K_3Mg_3$ | 13.7 | $N_2K_3Mg_3$ | 33.0 | $N_3K_3Mg_3$ | 38.1 | | | |
| Differences required for significance at 0.05 | | | 5.89 | | | | | |
| 0.01 | | | 8.57 | | | | | |

limiting factor ($N_1$ series). In the $N_2$ and $N_3$ series, trees receiving 20 and 100 ppm of magnesium in 1947 made a significantly greater growth in 1948 than those receiving 2 ppm, in all except the $K_1$ plots. Where potassium was limiting there was no significant growth response to increased concentrations of magnesium within the same N series. There was also no significant effect of $Mg_3$ (100 ppm) treatments over $Mg_2$ (20 ppm) within the same N and K series.

Growth response to varying potassium concentrations shows a similar pattern to that for magnesium. Greater growth due to increased potassium was obtained only when neither nitrogen nor magnesium was limiting.

## SUMMARY AND CONCLUSIONS

Sand culture experiments with young Stayman Winesap apple trees were conducted in the greenhouse for two growth periods. In the first year the trees were supplied with three levels of N, K, and Mg, in factorial combination; the concentrations of other elements were not varied. In the second season the trees were cut back to 60 cm in height and grown in sand with distilled water only.

Growth in the second season in distilled water was directly related to growth made the first season in nutrient culture. No significant growth response occurred in 1948 to varying amounts of either potassium or magnesium when nitrogen had been the limiting factor in 1947. Where nitrogen was not deficient, greater growth

due to increased magnesium was obtained only when potassium was not limiting. Similarly, there was a significant effect of reserve potassium on growth only when the trees received ample amounts of nitrogen and magnesium.

The results obtained in this study lend further emphasis to the concept that primary growth in the apple is largely dependent on the utilization of nutrients that were stored in the older tissues in the year, or years, prior to such growth. An adverse effect of reserve deficiencies on growth was strongly indicated in the second year when the trees were grown in distilled water, which suggests the possible use of this method of approach as an aid in interpreting nutrient interactions in sand culture experiments with deciduous fruit trees.

## Literature Cited

1. Edgerton, L. J. The effect of varying amounts of potassium on the growth and potassium accumulation of young apple trees. *Plant Phys.* 23: 112–122. 1948.
2. Roberts, R. H. Nitrogen reserve in apple trees. *Proc. Amer. Soc. Hort. Sci.* 18: 143–145. 1921.

# Foliar Diagnosis: The Range in the Zinc Content of Young Apple Trees[1]

By WALTER THOMAS, WARREN B. MACK, CYRIL B. SMITH, and FRANK N. FAGAN, *The Pennsylvania Agricultural Experiment Station, State College, Penn.*

IN connection with pruning experiments in one of the College orchards on 7-year-old Delicious, Stayman, and Rome apple trees, the leaf composition of certain trees having bark abnormalities has been reported for a number of nutrient elements, particularly boron, manganese, and iron (5). There was no indication that the necrotic condition was related to the content of any of these elements. The possibility that zinc might be a factor associated with the condition was based on the knowledge of the very low level of zinc in the soil taken from a strip of virgin land used in earlier experiments on apple trees planted in metal cylinders, the ultimate analysis of which soil has been reported (4). The soil of the orchard in this experiment belongs to the Hagerstown series and is situated about one quarter of a mile northwest of the site from which the soil for the apple cylinder experiments just referred to was taken.

## EXPERIMENTAL

During the first two seasons after planting, the rows were cultivated and the intervening strips were planted with sweet clover, following which the entire orchard was planted with Ladino clover to which a 4-12-4 fertilizer was applied annually, except in 1945, at the rate of 300 pounds per acre. In 1943 one-half ton of ground limestone was applied per acre. The growth of both trees and cover crops has been good.

On April 21, 1946, certain of the trees received differential applications of zinc sulfate, muriate of potash, and borax at the rate of 4, 5, and 3 pounds respectively per tree (Table I) broadcasted on an area about 6 inches from the trunks to below the branch extremities. The pH of the soil of this orchard ranges from 6.8 to 7.3. Although reduction in the availability of zinc commences between pH 7.0 and 7.5, the availability is not greatly reduced until the pH reaches 8.5.

Leaf samples were collected from the middle of the season's growth on August 16, 1945, before zinc applications were made and again on August 16, 1946, following the special fertilizer treatments in the spring of that year. The samples were thoroughly cleaned by brushing each leaf with cheesecloth immediately on removal from the tree. For the determination of trace elements, however, our present practice is to bring the leaf samples to the laboratory and wash each leaf carefully by brushing with cheesecloth moistened with water re-distilled from all pyrex glass.

Zinc was determined by the "dithizone" (diphenylthiocarbazone)

[1]Approved for publication on November 15, 1948 as paper No. 1487 of the Journal Series of the Pennsylvania Agricultural Experiment Station.

method (2) which has been approved as "tentative" by the Association of Official Agricultural Chemists, and has replaced the former $H_2S$-ferrocyanide procedure (1). Provided all conditions of extraction with "dithizone" are maintained the same as that of the blank, good agreements between duplicates can be attained by the method.

## Results

Table I gives the values for zinc in micrograms per gram of dry foliage, together with the fertilizer treatments and notes on the condition of the trees.

TABLE I

| No. | Zinc Micrograms Per Gram in the Dried Foliage | | Difference (B)-(A) | Relative Difference $\left(\frac{B-A}{B}\right)\times100$ | Treatments Apr 21, 1946 | Condition |
|---|---|---|---|---|---|---|
| | Aug 16, 1945 (A) | Aug 12, 1946 (B) | | | | |
| | | | | *Stayman* | | |
| A 4 | 34 | 50 | +16 | +32.0 | Zinc sulfate, muriate of potash, borax | Healthy |
| A 8 | 35 | 55 | +20 | +36.3 | Zinc sulfate | Bark rough; no necrosis |
| A 10 | 44 | 56 | +12 | +21.4 | Zinc sulfate, borax | Necrosis of bark |
| A 12 | 24 | 35 | +11 | +31.3 | None | Healthy; vigorous |
| A 16 | 30 | 27 | −3 | −11.1 | Zinc sulfate, muriate of potash, borax | Bark rough; no necrosis |
| C 16 | 35 | 50 | +15 | +30.0 | Zinc sulfate | Healthy |
| | | | | *Delicious* | | |
| B 2 | 29 | 50 | +21 | +42.0 | Zinc sulfate | Healthy |
| B 6 | 32 | 38 | +6 | +15.8 | Borax | Bark rough; no necrosis |
| B 8 | 43 | 55 | +12 | +21.8 | None | Necrosis |
| B 10 | 52 | 65 | +13 | +20.0 | Zinc sulfate, borax | Bark rough; no necrosis |
| B 16 | 30 | 42 | +12 | +28.5 | Muriate of potash | Necrosis |
| | | | | *Rome* | | |
| F 2 | 22 | 32 | +10 | +31.2 | Zinc sulfate | Bark rough; no necrosis |
| F 6 | 29 | 37 | +8 | +21.7 | Borax | Healthy |
| F 8 | 14 | 30 | +16 | +53.3 | None | Necrosis; spray injury |
| F 10 | 25 | 30 | +5 | +16.6 | Zinc sulfate, borax | Necrosis |

## Discussion of Results

*Stayman:*—Of the Stayman trees only one, A 10, was necrotic. This tree had the highest content of zinc (44 and 56 micrograms per gram) in both years. One of the healthiest and most vigorous of these Staymans (No. 12), moreover, had the lowest content of zinc in 1945 and next to the lowest in 1946.

The zinc content of five of these trees was higher in 1946 than in 1945. The exception is tree No. A-16 in which little difference in the values is shown. That this condition is not the result of the zinc applications is apparent from the fact that tree A-12 which did not receive any zinc sulfate is also considerably higher in 1946 than in 1945. The results indicate also that there is no consistent effect of muriate of potash or of borax on the absorption of zinc. The mean value in 1945 is 34.3 micrograms per gram, and in 1946 is 45.5 micrograms per gram.

*Delicious:*—Two of the Delicious trees (B-8 and B-16) were necrotic. In the other trees, although bark roughness was evident, necrosis was absent. As in the Staymans the healthiest and most vigorous tree (B-2) had in 1945 the lowest content of zinc (29 micrograms per gram . Of the necrotic trees, one (B-8) had a relatively high content of zinc (43 micrograms per gram) in 1945, whereas in the other necrotic tree the zinc content in that year was at a considerably lower level (30 micrograms per gram) but not significantly lower than that of the healthy tree (B-6) which had a content in this element of 32 micrograms per gram. In 1946 the zinc content of all trees was higher than in 1945 even in the trees B-8 and B-6 which did not receive zinc sulfate. The mean value in 1945 is 37.2 micrograms per gram and in 1946, 50.0 micrograms per gram.

*Rome:*—Two of the Rome trees (F-8 and F-10) were necrotic, one (F-8) from spray injury caused by an oil mixture. In 1945 the zinc content of this tree (14 micrograms per gram) is the lowest not only of the Romes but of the Stayman and Delicious varieties also. But the other necrotic tree (F-10) in 1945 has nearly as high a zinc content (25 micrograms per gram) as that of the very healthy tree (F-6) with a content of 29 micrograms per gram.

As with the other varieties the zinc content is higher in all of the Romes in 1946 than in 1945, whether zinc applications were made or not. The mean value for 1945 is 22.5 micrograms per gram and in 1946, 32.2 micrograms per gram.

In 1945 the range in the zinc content of the Staymans is from 24 to 44 micrograms per gram, in the Delicious the range is 29 to 52, and in the Romes much lower, namely, 14 to 29. In 1946 the ranges are, respectively, 35 to 56, 38 to 65, and 30 to 37. The fact that the range for the zinc content of the Romes is lower than the Stayman and Delicious both years suggests that the Romes may be characterized by having lower values for zinc than those of the other two varieties. And the fact that 9 of the 15 trees are either the same in rank with respect to the zinc content or within one rank of the same in each of the two seasons points to the fact that the higher zinc contents in 1946 are the result of differences in the meteorological conditions during the two seasons.

In none of the varieties is the content of zinc related to the necrotic condition of the bark. Eliminating the results for the Rome tree (F-8) injured by oil sprays, which in 1945 had the low content of zinc of 14 micrograms per gram, it is apparent that healthy trees may have relatively low zinc contents and necrotic trees higher but not abnormally high values for this element.

## Standard Values for Zinc in Young Apple Trees

Although no relationship of the zinc content of the leaves to the necrotic condition of the bark is apparent in this experiment, the data of Table I, nevertheless, are of interest as a contribution to knowledge of the variation in the range of the leaf content in this element of young apple trees and of their applicability as standard values for this element to trees of this age. In this connection Goodall and Gregory (3) have

assembled from the literature tables showing, for different species, values for the contents of the nutrient elements in relation to the incidence of deficiency and toxicity symptoms, as well as of proposed standard values of leaf nutrient content as related to plant performance.

Table I shows that in our young apple trees, the composition with respect to zinc of the median leaves of the season's growth taken at approximately the same physiological stage in two successive years ranges from 24 to 56 micrograms per gram of the dry foliage in Staymans; 29 to 65 micrograms per gram in Delicious; and 14 to 37 micrograms per gram in Rome. Considering all three varieties the range is rather wide, namely, from 14 to 65 micrograms per gram in the dry foliage. The data provide no indication of the critical limit for this element in young apple trees, but apparently it is below 14 micrograms per gram.

The wide range in the critical and standard values for the same species (in this case *Pyrus malus* L.) showing the same symptoms indicates the difficulties in formulating limiting values for the content of zinc deficient plants and also of standard values for normal plants. In the case of the micro-nutrient elements, particular attention needs to be paid to the complete removal from the leaves of extraneous material such as dust, soil, and spray residues; it is very necessary also to indicate the age and type of leaf sampled.

## Summary

Leaves selected on August 16, 1945, and on August 12, 1946, from the middle of the terminal growths on 7-year-old apple trees of three varieties, Stayman, Delicious, and Rome, which were growing in Ladino clover sod and which in addition to a basic fertilizer application of 300 pounds of 4-12-4 fertilizer per acre had received differential treatments of one or more of the following amounts of materials per tree in 1946—4 pounds of zinc sulfate, 5 pounds of muriate of potash, and 3 pounds of borax—were examined for their content of zinc both in 1945 and 1946. The content of zinc ranged from 14 to 52 micrograms per gram of dried foliage in 1945, and from 30 to 65 micrograms per gram in 1946. With one exception, all trees were higher in zinc content in 1946 than in 1945. The fact that the trees occupied approximately the same ranks with respect to each other in their zinc content in the two years indicated that the differences between the two years were the result largely of climatic influences in the two seasons, and that the differential treatments had no effect upon the zinc content of the leaves.

The apple trees here studied afford no evidence that their zinc content was inadequate; as has been stated, the bark abnormalities examined were not related to the zinc content of the leaves. From the evidence supplied by these trees, no estimate of the critical or standard value for zinc can be made; it would appear, however, that the zinc content of the leaves of apple trees of the characteristics described, under the existing environmental conditions, below which so-called deficiency symptoms appear, is less than 14 micrograms per gram of dried tissue.

## Literature Cited

1. Association of Official Agricultural Chemists. Methods of Analysis, 6th Ed. pp. 123–125. 1945.
2. Cowling, Hale, and Miller, E. G. Determination of small amounts of zinc in plant materials: A photometric dithizone method. *Ind. Eng. Chem. Anal. Ed.* 13: 145–149. 1941.
3. Goodall, D. W. and Gregory, F. G. Chemical composition of plants as an index of their nutritional requirements. *Tech. Communication* No. 17. *Imp. Bur.* of *Hort.* and *Plantation Crops.* Penglais, Aberystwyth, Wales. 1947.
4. Thomas, Walter. Ultimate analysis of the mineral constituents of a Hagerstown silty clay loam and occurrence in plants of some of the elements found. *Soil Sci.* 15: 1–18. 1923.
5. ————, Mack, Warren B., and Fagan, Frank N. Foliar diagnosis: Internal bark necrosis in young apple trees. *Proc. Amer. Soc. Hort. Sci.* 50: 1–9. 1947.

# Preliminary Studies on a Chlorotic Disorder of Fruit Trees in Peiping Associated Primarily with a Deficiency in Iron

By Tsuin Shen and Hsiang Tseng, *National Tsing Hua University, Peiping, China*

Abstract

This paper will be published in full in *Acta Agriculturae, of the College of Agriculture, National Tsing Hua University, Peiping, China.*

A serious and widespread chlorotic disorder of fruit trees is found to occur in Peiping and its vicinity on alkaline-calcareous soils. Affected trees display symptoms of low growth vigor, chlorosis, necrosis, premature abscission of the leaves, dieback of branches and reduced size of fruits which are poor in color and quality. The characteristic chlorotic pattern is the appearance of light yellow areas between the veins presenting a contrasting picture of a fine network of green veins on a much lighter background. The symptoms are most prominent from June to August, the rainy season of Peiping. After August, chlorosis becomes less conspicuous, many chlorotic leaves partially recovering and those severely affected falling off. Occasionally, symptoms resembling closely "little-leaf" and "rosette" are also observed, being particularly noticeable in apples. While many of these little leaves are chlorotic, some remain green.

Spray and injection experiments were conducted in 1948 in three commercial orchards using peaches, apples and pears as materials. The data show that diseased branches responded favorably to sprays and injections of iron salts (both ferrous sulphate and ferric citrate, applied either during the dormant season or in the summer) as evidenced by their recovery from chlorosis and more or less increase in growth. Different branches, however, responded in varying degrees to the same treatment. As a rule, the improvement in color was not accompanied by a correspondingly marked improvement in growth. Iron sprays applied in summer resulted consistently in the development of small green spots on the leaves approximately 1 week after treatment. With injections made in the form of dry powder, it was noted that in several cases, the leaves on the same side of the point of injection turned green while those on the other side remained yellowish. The curative effect of these measures, however, was transitory, lasting for only 2 to 3 months.

Some response was also obtained with the application of zinc sulphate, zinc oxide, and to a less extent, manganese sulphate. The spray or injection of zinc salts brought some of the branches treated to normal green and more or less alleviated little-leaf. No effect from spraying with magnesium sulphate was observed and soil application of borax was of doubtful value. The planting of alfalfa under the trees resulted in remarkable recovery in three of the five trees treated.

The results obtained from experiments employing the technique of leaf-stalk and leaf-tip injections (1) agree with those from orchard

experiments in that ferrous sulphate produced an immediate improvement in color but are at variance with those from orchard experiments in that the application of zinc sulphate gave only indifferent results.

In light of the symptoms observed and the results obtained from spray and injection experiments, it appears that the chlorotic disorder of fruit trees in the Peiping area is associated primarily with a deficiency in iron with possibly incipient zinc and manganese deficiencies as complicating factors.

## Literature Cited

1. Roach, W. A. The use of leaf analysis, plant injection and curative treatment for the determination of mineral deficiency in plants. *Ann. Appl. Biol.* 34: 153–159. 1947.

# Boron Requirements of Plums

By Carl J. Hansen and E. L. Proebsting, *University of California, Davis, Calif.*

Boron deficiency occurs on European plums *(Prunus domestica)* in the Sierra Nevada foothills of California. The orchards thus far studied are in Placer and El Dorado counties and are usually on Aiken and Sites series soils. A few, however, are on the boundary between the Aiken and Holland series. The winter rainfall is usually adequate to bring the rather shallow soil up to field capacity. However, irrigation is nearly always necessary during the dry summer season.

The only symptoms that appear consistently are found on the fruit. The brown sunken areas that form in the flesh of the fruit (Fig. 1) may consist of a single small spot or may involve practically the whole fruit. The brown flesh beneath the sunken areas is firm in texture and in severe cases extends to the pit. Fruits showing symptoms of boron deficiency usually color up earlier than normal fruits and drop to the ground. In some cases gum pockets may be formed in the flesh of the fruits. The number of plums that show deficiency symptoms varies from a few fruits to the entire crop. Some trees reach full size before boron deficiency symptoms appear. In other cases, however, the symptoms appear the first season fruit is produced. The trouble is sometimes found on the same tree for several years in succession, but in other cases it does not recur for several years. The prune drouth spot described by Blodgett and Colwell (1) is probably not the same as the trouble described above. Boron deficiency was suspected as a possible cause of drouth spot but they did not obtain positive response to boron treatments. Burrell and Heinicke (2) describe a new New York prune trouble with symptoms similar to those found in Idaho by Blodgett and Colwell. Boron applications were not effective in eliminating the symptoms. It is probable that the New York trouble is different from that found in California. McLarty and Wilcox (3) mention that prune drouth spot may be prevented by the use of boron. However, it is not known if this trouble is the same as that found in California.

European plums such as President, Giant, and Diamond are the only plums in California that have to date shown symptoms of boron deficiency. Japanese plums *(Prunus salicina)* that are growing adjacent to boron-deficient European plums and pears appear to be normal. The "heat spot", "Kelsey spot" or "drouth spot" (4) of Japanese plums differs in symptoms from the boron deficiency of European plums primarily in the time of appearance, the sharpness of definition of spot margins and the lack of gum pockets. The heat spot develops only in the period of about 10 days preceding harvest, while boron deficiency symptoms often occur much earlier. Fruits damaged by heat spot may not drop badly in contrast to the boron-deficient fruit. The heat spot is typically very sharply defined. Boron-deficient spots may be nearly as diffuse as sunburn.

All leaf and fruit analyses reported were made by the electrometric titration method described by Wilcox (5). Saturated calomel and glass were used for electrodes. The leaf samples were taken from the entire

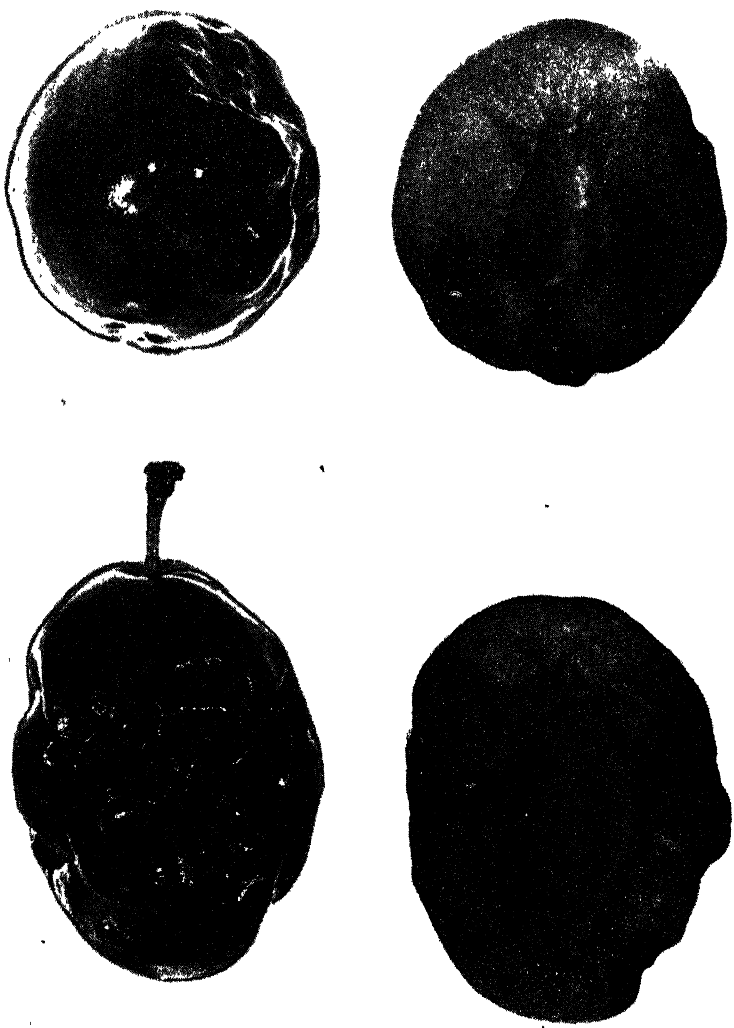

FIG. 1. Symptoms of boron deficiency on President plum fruits.

length of shoots that had made moderate growth. Shoots that had made very vigorous growth and spurs were avoided. Nearly all the leaf and fruit samples included in this report were collected during the last week in July or the first week in August. All samples were washed once in distilled water.

The boron concentrations in normal and deficient President plum leaves and fruits are included in Table I. All trees are in the same

TABLE I—THE BORON CONTENT OF PRESIDENT PLUM LEAVES AND FRUITS (ORCHARD NUMBER 9, PLACER COUNTY) SAMPLES COLLECTED ON AUGUST 4 AND 7, 1948

| Tree | Condition of Tree | Boron in Dry Matter (Ppm) | | |
|---|---|---|---|---|
| | | Leaves | Injured Fruits (Flesh) | Normal Fruits (Flesh) |
| 1 | Severe deficiency symptoms | 22 | 6 | 7 |
| 2 | Severe deficiency symptoms | 20 | 5 | 12 |
| 3 | Severe deficiency symptoms | 22 | 7 | 5 |
| 4 | Severe deficiency symptoms | 21 | 7 | 6 |
| 5 | Severe deficiency symptoms | 20 | 5 | 8 |
| 6 | Normal | 52 | — | 53 |
| 7 | Normal | 47 | — | 48 |
| 8 | Normal | 53 | — | 61 |
| 9 | Normal | 53 | — | 61 |
| 10 | Normal | 47 | — | 37 |

orchard but the five trees showing symptoms of boron deficiency are about one-quarter mile from the normal ones. These differences in boron content are greater than are usually found in the same orchard but there is no record of boron compounds having been applied. With the exception of tree No. 2, the "normal" and injured fruits from the boron-deficient trees contained approximately the same amount of boron.

The data in Table II show the effect of soil applications of borax on the boron content of Giant plum leaves and fruits. Both the 1- and 2-pound borax treatments resulted in injury during 1945 and 1946. However, only slight injury resulted from the 1-pound application. Tree 4 may have gotten some boron from tree 1 which is adjacent to it. The increase in the boron concentration of tree 2 must be due to natural variations in the availability of boron since it was isolated from all treated trees by a number of guard rows. Orchard No. 2 is growing in a deep, fertile, Yolo series soil in the Sacramento Valley. The level of boron in this orchard is thought to be normal so the analyses are included for comparison with those from the areas where boron deficiency is found. These trials indicate that a single soil application of borax is effective for several years and that a dosage smaller than 1 pound per tree should be tried.

President plum trees (Table III) responded to borax treatments as low as .5 pound per tree. One of the untreated trees (orchard 3, tree 2W8) showed a considerably higher concentration of boron in 1945, 1946, 1947 and 1948 than in 1944. At least part of this increase is probably the result of boron being carried down hill from a borax treated pear orchard. The trees treated with .5 pound of borax, however, were located in such a way that movement of this sort could not occur.

All plum trees included in these trials that received a soil treatment of borax in the late summer or fall were free of deficiency symptoms the following growing season. However, when the treatment was delayed until late winter or early spring, an occasional tree did not recover completely the first season. Tree 6–3 in orchard 6 (Table IV) is an example of such a tree. Each of 37 President plum trees in orchard 6 received a soil treatment of 1.3 pounds of borax in February

TABLE II—THE BORON CONTENT OF GIANT PLUM LEAVES AND FRUITS (ORCHARD NUMBER 1, PLACER COUNTY; ORCHARD NUMBER 2, SOLANO COUNTY)

| Orchard | Tree | Pounds Borax Per Tree | Date Borax Added | Condition of Tree | Boron in Dry Matter (Ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1944 | | 1945 | 1946 | 1947 | | 1948 |
| | | | | | Leaves | Fruit (Flesh) | Leaves | Leaves | Leaves | Fruit (Flesh) | Leaves |
| 1 | 1 | 1 | Aug 25, 1944 | Severe deficiency symptoms in 1944; no deficiency symptoms in 1945, 1946, 1947 and 1948 | 11 | 3 | 70†* | 62†* | 78* | 81* | 56* |
| 1 | 2 | 0 | ——— | Normal | 26 | 8 | — | — | 38 | 17 | 35 |
| 1 | 3 | 2 | Aug 25, 1944 | Severe deficiency symptoms in 1944; no deficiency symptoms in 1945, 1946, 1947 and 1948 | — | — | 93†* | 66†* | 92* | — | 57* |
| 1 | 4 | 0 | ——— | Severe deficiency symptoms in 1944 and 1945; normal in 1946 and 1947 | — | — | 22 | 33 | 45 | — | Dead |
| 2 | 1 | 0 | ——— | Normal | 55 | 37 | — | 62 | — | — | — |

*Analyses made after borax had been added to the soil.
†Tree injured by an excess of boron.

TABLE III—THE BORON CONTENT OF PRESIDENT PLUM LEAVES AND FRUITS (ORCHARD NUMBER 2, SOLANO COUNTY; ORHARDS NUMBER 3 AND 4, PLACER COUNTY)

| Orchard | Tree | Pounds Borax Per Tree | Date Borax Added | Condition of Tree | Boron in Dry Matter (Ppm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1944 | 1945 | 1946 | 1947 | | 1948 |
| | | | | | Leaves | Leaves | Leaves | Leaves | Fruit (Flesh) | Leaves |
| 2 | —— | 0 | —— | Normal | 53 | — | 50 | — | — | — |
| 3 | 2W8 | 0 | —— | Severe deficiency symptoms in 1944; normal in 1945, 1946, 1947 and 1948 | 12 | 64 | 39 | 40 | 51 | 60 |
| 3 | 2W10 | 1 | Aug 25, 1944 | Severe deficiency symptoms in 1944; normal in 1945, 1946 and 1947 | 12 | 71* | 51* | 45* | 69* | Dead |
| 3 | 2D | 0.5 | Oct 18, 1945 | Severe deficiency symptoms in 1945; normal in 1946, 1947 and 1948 | — | 22 | 46* | 53* | — | 53* |
| 3 | 3D | 0.5 | Oct 18, 1945 | Severe deficiency symptoms in 1945; normal in 1946, 1947 and 1948 | — | — | 56* | 53* | — | 56* |
| 4 | 3 | 0.5<br>1 | Oct 18, 1945<br>Fall 1946 | Severe deficiency symptoms in 1945; normal in 1946, 1947 and 1948 | — | 26 | — | — | — | — |
| 4 | 6N | 1 | Fall 1946 | Normal | — | 31 | — | — | — | — |
| 4 | 2 | 0.5<br>1 | Oct 18, 1945<br>Fall 1946 | Severe deficiency symptoms in 1945; normal in 1946, 1947 and1948 | — | — | 50* | — | — | 66* |

*Analyses made after borax had been added to the soil.
Note: No excess boron injury was evident on the above trees.

of 1946. All except three trees were free of boron deficiency symptoms in the summer of 1946 and in these three cases the injury was slight to moderate. All the 31 adjacent untreated trees showed severe boron deficiency symptoms.

TABLE IV—THE BORON CONTENT OF PRESIDENT PLUM LEAVES AND FRUITS (ORCHARDS NUMBER 6 AND 8, PLACER COUNTY; ORCHARD NUMBER 7, EL DORADO COUNTY)

| Orchard | Tree | Pounds Borax Per Tree | Date Borax Added | Condition of Tree | Boron in Dry Matter (Ppm) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1946 | 1947 | |
| | | | | | Leaves | Leaves | Fruit (Flesh) |
| 6 | 2–5 | 3 | Feb 1947 | Severe deficiency symptoms in 1946; normal in 1947. | 25 | 69* | 157* |
| 6 | 1–6 | 3 | Feb 1947 | Severe deficiency symptoms in 1946; normal in 1947. | 28 | 60* | 106* |
| 6 | 3–6 | 3 | Feb 1947 | Severe deficiency symptoms in 1946; normal in 1947. | 24 | 76* | 114* |
| 6 | 8–11 | 3 | Feb 1947 | Normal | 29 | 74* | 250* |
| 6 | 1–4 | 1.3<br>3 | Feb 1946<br>Feb 1947 | Normal | 60* | 75* | 337* |
| 6 | 2–4 | 1.3<br>3 | Feb 1946<br>Feb 1947 | No deficiency symptoms in 1946 and 1947. | 54* | 77*† | 173*† |
| 6 | 3–4 | 1.3<br>3 | Feb 1946<br>Feb 1947 | No deficiency symptoms in 1946 and 1947. | 53* | 72*† | 154*† |
| 6 | 6–3 | 1.3<br>3 | Feb 1946<br>Feb 1947 | Showed some deficiency symptoms in 1946 but not in 1947 | 36* | 74*† | 321*† |
| 7 | — | 0 | ——— | Some deficiency symptoms in 1946. | 29 | — | — |
| 8 | 1 | 1 | Oct 30, 1946 | Some deficiency symptoms in 1946; normal in 1947. | 24 | 51* | 75* |

*Analyses made after borax had been added to the soil.
†Tree injured by an excess of boron.

Trees that showed visible symptoms of excess boron are indicated in Tables II and IV. Unfortunately, visible symptoms of excess boron (6) are usually found only on watersprouts and other vigorous growth, so some of the slow growing trees that were sampled were probably injured by boron excess but the trouble could not be recognized.

Leaves from boron-deficient President plum trees in orchard 5 (Table V) contained approximately the same concentrations of boron as those from adjacent untreated but normal trees. This would indicate that the normal trees were on the border line of deficiency and that symptoms might have appeared if boron had not been added. A block of 20 trees in orchard 5 was treated on January 16, 1946, at the rate of 2 pounds of borax per tree. All the treated trees were normal in the summer of 1946. Of the 44 untreated trees that were adjacent to three sides of the treated block, 22 showed severe boron deficiency symptoms.

With the exception of the tree 6–3 in orchard 6 (Table IV) no boron deficiency symptoms were found on trees whose leaves contained 30 ppm or more boron, but when 25 ppm or less was present the symptoms were always found. Leaf concentrations ranging from 26 to 29 ppm were obtained from both normal and deficient trees. Leaves from tree 6–3 contained 36 ppm boron when they were sampled on July 29, 1946. It is considered likely that the boron content at the time of sampling was higher than when deficiency symptoms were

TABLE V—THE BORON CONTENT OF PRESIDENT PLUM LEAVES AND FRUITS (ORCHARD NUMBER 5, PLACER COUNTY)

| Tree | Pounds Borax Per Tree | Date Borax Added | Condition of Tree | Boron in Dry Matter (Ppm) | | | |
|---|---|---|---|---|---|---|---|
| | | | | 1946 | 1947 | | 1948 |
| | | | | Leaves | Leaves | Fruit (Flesh) | Leaves |
| 2–5 | 1 | Fall 1946 | Severe deficiency symptoms in 1946; no deficiency symptoms in 1947 and 1948. | 27 | 63* | 166* | 66* |
| 6–6 | 1 | Fall 1946 | Severe deficiency symptoms in 1946; no deficiency symptoms in 1947 and 1948. | 25 | 64* | 140* | 66* |
| 4–6 | 1 | Fall 1946 | Severe deficiency symptoms in 1946; no deficiency symptoms in 1947 and 1948. | 29 | 60* | 226* | 57* |
| 4–8 | 1 | Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948. | 29 | 79* | 131* | 60* |
| 3–6 | 1 | Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948. | 31 | 89* | 149* | 60* |
| 2–6 | 1 | Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948. | 29 | 54* | 162* | 59* |
| 8–2 | 2<br>1 | Jan 16, 1946<br>Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948. | 48* | 89* | 159* | 75* |
| 6–2 | 2<br>1 | Jan 16, 1946<br>Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948 | 61* | 97* | — | 73* |
| 4–3 | 2<br>1 | Jan 16, 1946<br>Fall 1946 | No deficiency symptoms in 1946, 1947 and 1948 | 50* | 83* | 323* | 71* |

*Analyses made after borax had been added to the soil.
Note: Nearly all the trees in orchard number 5 showed some excess boron injury in 1947 and 948.

initiated. It should be noted that this tree was not treated until February.

The concentration of boron in the fruit flesh of trees deficient in boron was lower than that in the leaves. However, more boron was found in the fruit flesh than in the leaves when the boron level in the tree was high.

Growers in the areas where boron deficiency occurs have made rather extensive commercial applications of borax. Good results were secured when the suggested rate and time of application was followed. Orchard No. 9 in Placer County (Table I) is one of the few plum orchards in the boron-deficient areas that has not been treated with borax. As previously indicated, severe boron deficiency symptoms were found in parts of this orchard in 1948.

Plum trees in California have been injured by an excess of boron, either introduced in the irrigation water or occurring naturally in the soil. Boron should be used when needed in the areas discussed in this paper, but care should be taken not to apply too much. It should not be applied in those areas where an adequate or an excessive supply is present.

Some excess boron injury occurred when borax was used at the rate of 1 pound per tree, so it is suggested that commercial applications be made at the rate of .5 pound of borax per tree (approximately 50 pounds per acre). If boric acid is used, the amount should be about two-thirds as much. The borax was broadcast on the surface of the soil under the branches of the trees. It is not known how long a single application will last but present indications are that .5 pound of borax per tree will provide an adequate amount for at least 3 years.

## Summary

Brown sunken areas were found in the flesh of boron deficient European plum fruits. The symptoms were eliminated when borax was broadcast on the surface of the soil in the late summer or fall. The boron contents of normal and deficient leaves and fruits are reported.

### Literature Cited

1. Blodgett, E. C., and Colwell, W. E. Relation of drought spot of prunes to boron content of fruit. *Phytopath.* 29: 650–651. 1939.
2. Burrell, A. B., and Heinicke, R. M. First progress report on prune drouth spot. *Proc. Amer. Soc. Hort. Sci.* 36: 275–278. 1939.
3. McLarty, H. R., and Wilcox, J. C. From Death Valley to fertile fruit lands of British Columbia comes invigoration for trees. *Country Life in British Columbia* 20: 7 and 18. December 1936.
4. Proebsting, E. L. Kelsey spot of plums in California. *Proc. Amer. Soc. Hort. Sci.* 34: 272–274. 1937.
5. Wilcox, L. V. Determination of boron in plant material. *Ind. Eng. Chem., Anal. Ed.* 12: 341–343. 1940.
6. Hansen, Carl J. Influence of the rootstock on injury from excess boron in French (Agen) prune and President plum. *Proc. Amer. Soc. Hort. Sci.* 51: 239–244. 1948.

# Further Studies of the Effectiveness of Organic Mulches in Correcting Potassium Deficiency of Peach Trees on a Sandy Soil[1]

By CLARENCE E. BAKER, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

THE effectiveness of several organic mulches in correcting potassium deficiency in young Red Haven peach trees on Coloma loamy fine sand, based on one year's results, was reported in 1947 (1). Another season's observations confirm these results and give indications that the recovery made by the mulched trees is complete.

The trees under observation are located at the east side of the planting in an area four trees wide and 35 trees long north and south. Treatments consist of single tree plots, randomized among the trees that originally showed moderate or serious K deficiency symptoms, with at least eight replications in each treatment.

During the summer of 1948, the unmulched check trees that had exhibited marked symptoms of potassium deficiency in 1946 and 1947, developed the symptoms for the third season. These untreated trees are much smaller and more variable in size. Some are seriously dwarfed. Their leaves are small, narrow, and the edges tend to roll upward toward the center. Early in the season they are light green, but become reddish yellow, with marginal scorch and other necrotic areas late in the summer, giving the tree a bronzed appearance. The diameter of the shoots and branches is small in comparison with that of healthy trees. The leaf symptoms usually begin to appear in July, in northern Indiana, but they do not reach their maximum intensity until the middle of September, or later.

The treated trees, which also were originally starved for potassium made a rapid recovery following the application of mulches of manure, straw, and soybean hay in the late summer of 1946. During the 1947 season they made a normal and vigorous growth, as previously described (1). In 1948 this vigorous growth was repeated. The trees again appeared to be perfectly normal in every respect and now are as large and as well formed as any trees in the orchard.

No mulch has been applied since the original treatments in the late summer of 1946. Much of the material has been disced into the soil during the periods in summer when the orchard is cultivated, and is now partially decomposed.

A small amount of fruit was produced in this orchard in 1948, its fourth growing season, in spite of a late spring freeze. Most of the mulched trees set a few fruits which developed into normal peaches. None of the unmulched check trees produced fruit buds in 1947.

The unmulched trees in another part of the orchard to which 0–0–50 was applied in the spring of 1946, have shown no further potassium deficiency and are making satisfactory growth.

As in past seasons, all of the trees in the orchard received a spring

[1]Station Journal Paper No. 373.

application of ammonium nitrate at the rate of about ½ pound per tree.

The apple trees, among which the peach trees are interplanted, have exhibited no indications of potassium hunger, but appear to be growing normally, even in locations where surrounding peach trees show potassium deficiency symptoms.

## 1948 Leaf Analyses

During the summer of 1948, leaf samples for chemical analyses were taken at intervals during the summer. Each sample represented a composite of 60 leaves from each of three trees, taken from the median portion of the terminal growth. In the case of the manure and the straw mulch treatments, as well as the untreated check trees, a group of three trees in the north half of the experimental block (north series) and a group of three trees in the same treatments in the south portion of the block (south series) was sampled. All of the trees mulched with soybean hay were in the south portion of the block. The potassium values for the different treatments are shown in Table I.

TABLE I—The Effect of Various Mulches on the Potassium Content of Leaves From Terminal Growth (Bassett Peach Orchards — 1948)

| Treatment | K as Per Cent of Dry Weight | | |
|---|---|---|---|
| | Jun 3 | Jul 2 | Aug 23 |
| Untreated check—N series | 0.74 | 0.57 | 0.41 |
| Untreated check—S series | 0.83 | 0.56 | 0.39 |
| Manure mulch—N series | 2.04 | 2.28 | 1.85 |
| Manure mulch—S series | 2.02 | 2.07 | 1.82 |
| Straw mulch—N series | 1.96 | 1.61 | 1.18 |
| Straw mulch—S series | 1.77 | 1.76 | 1.28 |
| Soybean hay mulch—S series | 1.85 | 1.75 | 1.36 |

None of the trees upon which the data in Table I are based have received potassium fertilizers, with the exception of an application of about 200 pounds per acre of 0–14–7 applied for the cover crop in the fall of 1946. This fertilizer was distributed uniformly over the whole orchard, including the experimental area.

The leaves from the untreated check trees were low in potassium throughout the season in comparison with leaves from the mulched trees. That these figures are well within the "starvation" range is borne out by the behavior of the trees. Leaves from the mulched trees all show a favorable potassium content. The potassium in leaves from trees mulched with manure tended to be somewhat higher than in leaves from trees mulched with soybean hay or straw.

## Literature Cited

1. Baker, Clarence E. The effectiveness of some organic mulches in correcting potassium deficiency in peach trees on a sandy soil. *Proc. Amer. Soc. Hort. Sci.* 51:205–208. 1948.

# Observations on Boron Deficiency in Apples in Southwestern Michigan[1]

By Oscar J. Dowd, *Paw Paw, Mich.*

During the last four years, 21 apple growers in southwestern Michigan have called attention to some apple trees on light sandy soils that were not making satisfactory growth. In some instances, affected trees have been severely pruned or removed.

These trees show typical symptoms of "apple measles" as described by Young and Winter (1) or boron deficiency as described by Burrell (2). This condition is illustrated in Fig. 1. These bark symptoms have been observed on such varieties as Red Delicious, Jonathan, McIntosh, Steeles Red, Baldwin, Red Astrachan and Yellow Transparent growing on the Boyer, Coloma, Ottawa, Oshtemo or Plainfield soil types. These are light sandy acid soils commonly found in southwestern Michigan.

Light applications of borax have been recommended in several instances on the basis of work done by Young and Winter and unpublished work done by Donald Cation of Michigan State College. A notable growth response has been observed in orchards where borax has been applied.

Three orchards were selected for this study. These are located near the towns of Bangor, Paw Paw and Mattawan in Van Buren County. Two trees were selected in each orchard to compare the effect of borax applications with no treatment. The 9-year-old orchard at Bangor has been fertilized with the usual application of nitrogen fertilizer and has been mulched with barnyard manure. The Paw Paw orchard is an abandoned sod orchard about 35 years old that has not been fertilized for several years. The 15-year-old orchard at Mattawan is on very light sandy soil that received a light application of 3–12–12 this spring.

The treated trees received borax as follows: Bangor orchard, 1 tablespoonful in the fall of 1946, 1 tablespoonful in the spring of 1947 and another in the spring of 1948; the Paw Paw orchard, 1 pound of borax applied April 3, 1948; the Mattawan orchard, ½ pound of borax applied in the spring of 1948. Table I shows the effect of borax applications on the 1948 terminal growth and the boron content of leaves in three orchards.

The boron content of apple leaves was increased 7 to 15 parts per million. The greatest increase occurred where 1 pound of borax was applied to the tree. The growth response was greatest in the young orchard. The lack of growth response in the Mattawan orchard is apparently due to low fertility.

Fig. 2 shows a comparison of growth made by the treated tree and the untreated tree in the Bangor orchard.

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[1]The Soil Conservation Service gave the author permission to make this study on his own time. Grateful acknowledgement is made to Dr. A. L. Kenworthy, Horticultural Department of Michigan State College for his assistance and suggestions.

FIG. 1. Apple bark symptoms of boron deficiency. Left—purplish pimples on young twig; center—rough cracked bark on small twig; right—advanced stage.

Light applications of borax are believed to be needed in many apple orchards that are making unsatisfactory growth on the light sandy soils of southwestern Michigan. Some of these orchards appear to be border line cases with definite deficiency symptoms on only a few trees

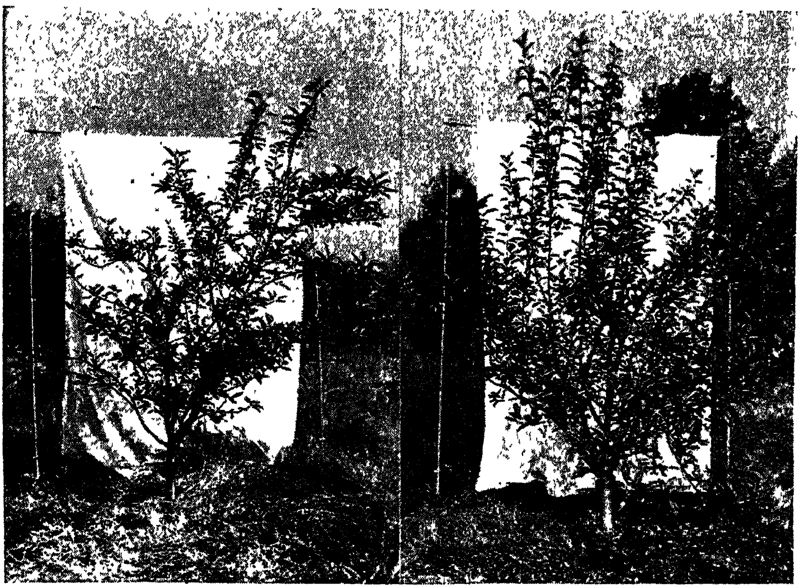

FIG. 2. Left—Unsatisfactory growth made by untreated Delicious; right—growth made by Delicious apple after receiving application of borax.

TABLE I—EFFECT OF BORAX TREATMENTS ON GROWTH AND BORON CONTENT OF LEAVES

| Orchard Location | Soil Types | Terminal Growth (Inches) | | Boron in Leaves (Ppm)* | |
|---|---|---|---|---|---|
| | | Treated | Untreated | Treated | Untreated |
| Bangor | Coloma | 21.3 | 3.9 | 31.5 | 20.5 |
| Paw Paw | Oshtemo | 8.7 | 3.3 | 36.8 | 21.3 |
| Mattawan | Boyer | 7.0 | 5.0 | 30.3 | 23.4 |

*Total boron as expressed in ppm in dry matter of leaf samples taken July 24, 1948. Analyses were made by Dr. E. J. Benne, Department of Agricultural Chemistry, Michigan State College.

while the remainder of the orchard is making unsatisfactry growth without definite symptoms of boron deficiency. Growers should be advised to make small test treatments before making general applications.

## LITERATURE CITED

1. YOUNG and WINTER. Effect of boron, manganese and lime on the control of apple measles. *Ohio State Bi-Mo. Bul.* 188. 1937.
2. BURRELL, A. B. The boron-deficiency disease of apples. *N. Y. (Cornell) Ext. Bul.* 428. 1940.

# Tests on Foliar Fertilization of Peach Trees With Urea

By J. H. WEINBERGER, *U. S. Horticultural Field Laboratory, Ft. Valley, Ga.,* VICTOR E. PRINCE, and LEON HAVIS, *Plant Industry Station, Beltsville, Md.*

WHEN early maturity and high color of peach fruits are desired, it is usually necessary to have the tree in as low nitrogen condition as practicable at the time of fruit harvest. Foliar fertilization offers a possible means of providing quickly available nitrogen to the tree, which should soon use it in growth with a minimum of effect on fruit color and maturity. Studies on the use of urea for apple foliar fertilization (1, 2) suggest its possible value for peaches. The present investigations were conducted at Fort Valley, Georgia, and Beltsville, Maryland, to determine the effects of time and number of applications of urea on the foliage and fruits of peaches.

## FORT VALLEY TESTS

Blocks of 45 trees were selected for uniformity in 4-year-old commercial Dixigem and Sullivan Early Elberta orchards that had received no nitrogen fertilizer the previous year. These blocks were divided into nine plots of five trees each. Three plots of each variety were given spray applications of urea on March 30, 1948 at a concentration of 5 pounds per 100 gallons of water. About 3 gallons of spray were applied per tree. The fruits were slightly past the shuck-split stage. The application to the same trees was repeated on April 12 and April 23, making three applications in all. Three plots of each variety were left as check plots, while the third series of plots for each variety was given a soil application of ½ pound of urea per tree on March 30. One-half pound was approximately equivalent to the amount of fertilizer, or dosage, each tree received in the three spray applications. Observations on foliage condition were made through the season and at harvest. Leaf samples for nitrogen determination were taken at harvest. Yield records and terminal growth records also were made.

Observations made on leaf color during the season and at harvest time failed to show that the foliage spray applications of urea affected leaf color. The soil application of urea resulted in a deeper green color of the foliage at fruit maturity. Foliar application likewise did not have an observable effect on the color of the fruit at maturity, but soil applications definitely delayed the coloring of the fruit. Leaf analysis showed no significant difference in nitrogen content at harvest (Table I).

Harvest records (Table I) show that neither foliar nor soil application affected the yield of fruit significantly. The soil treatment delayed maturity of fruit significantly in both the Dixigem and Sullivan Elberta trees, as indicated by the per cent of the crop harvested in the first two pickings. The foliar application showed no significant delay in maturity. Terminal growth measurements (Table I) show that foliar application of urea did not increase terminal growth of the trees. With the Dixigem variety terminal growth on the check and the foliar

TABLE I—EFFECT OF UREA APPLICATIONS ON YIELD, MATURITY, TERMINAL GROWTH, AND NITROGEN CONTENT OF LEAVES

| Treatment | Dixigem | | | | Sullivan Early Elberta | | | |
|---|---|---|---|---|---|---|---|---|
| | Yield (Bu) | Per Cent Harvested First Two Pickings | Terminal Growth (Inches) | Nitrogen in Leaves (Per Cent) | Yield (Bu) | Per Cent Harvested First Two Pickings | Terminal Growth (Inches) | Nitrogen in Leaves (Per Cent) |
| Check ........ .... | 2.34 | 33.6 | 15.0 | 2.10 | 2.20 | 42.2 | 15.7 | 2.05 |
| Foliar application | 2.45 | 26.3 | 14.9 | 2.16 | 2.52 | 31.7 | 14.7 | 2.21 |
| Soil application.... | 2.32 | 22.9 | 15.9 | 2.15 | 2.10 | 21.0 | 16.2 | 2.08 |
| L.S.D. at .05 level. | 0.35 | 8.3 | 0.6 | 0.21 | 0.48 | 17.6 | 1.5 | 0.24 |

application plots was almost identical. With the Sullivan Elberta variety, growth in the check plots averaged 15.7 inches and on the foliar application plots, 14.7 inches. The difference was not significant. The soil application of urea increased the terminal growth slightly; only in the case of the Dixigem variety is the difference due to treatment significant.

From these results it appears that foliar applications of urea to the peach trees were practically ineffective, while soil applications made in equivalent amounts had a small influence on maturity of fruit and terminal growth. The reason for the failure is not understood, for the leaves of the trees and the ground received all of the urea in the foliar application plots. Possibly the time of application was important. The third foliar application of urea was made April 23, or 24 days after the soil application. From April 15 to harvest there was only a little over an inch of rainfall, so that it is doubtful that much of the last foliar application reached the roots of the trees before first harvest.

## BELTSVILLE TESTS

Trees used were selected for uniformity from a planting of 4-year-old Redhaven and Sunhigh varieties. These tests in 1948 included only trees that had not been fertilized previously that year. Five trees of each variety were used. Each tree was divided into five parts by using scaffold limbs for different treatments. The two concentrations of urea used principally were 5 and 10 pounds per 100 gallons of water. The urea was applied either once or twice during the season. As much as possible without excessive run-off was applied.

Each of the 10 trees included 1 scaffold limb with the treatment listed below.

1. One application, concentration of 5 pounds per 100 gallons.
2. Two applications, concentration of 5 pounds per 100 gallons.
3. One application, concentration of 10 pounds per 100 gallons.
4. Two applications, concentration of 10 pounds per 100 gallons.
5. No treatment (control).

The first spray application was made April 12, 1948,[1] or 7 days after full bloom, and the second application on June 4, 1948. In all cases a

[1]Since a rain followed in about an hour after the first application on April 12, it was repeated.

heavy canvas was placed under the trees while being sprayed to prevent any of the urea from reaching the soil.

Observations of foliage conditions were made through the season. Records of fruit color and ripening dates were made at harvest. Leaf samples were taken for nitrogen analysis on May 6, 1948, May 21, 1948, June 4, 1948, and July 8, 1948.

Observation failed to show any difference in leaf color between treatments. No differences in fruit color or ripening dates were found at harvest. Results of the leaf analysis at the four sampling dates, showed no significant differences in nitrogen content in the different treatments. An analysis of variance of the data showed significance only for time of sampling. The average nitrogen content of the leaves on May 6 was approximately 2.9 per cent while on July 8 it was approximately 2.5 per cent.

Limited tests with concentrations of 25 and 50 pounds of urea per 100 gallons of water resulted in no leaf color response. These treatments were applied on May 10, and the leaves showed no significant difference in nitrogen content of the foliage from the control. Both of these high concentrations, however, caused some marginal burning of leaves. Slightly more injury was noted where the 50-pound rate was used than for the 25-pound rate, but even here it was not severe. Only slight defoliation occurred.

## Conclusions

It may be concluded from these tests with urea on foliage of peach trees that this method of applying nitrogen was not effective either at Beltsville, Maryland, or Fort Valley, Georgia. If any of the nitrogen in the urea was utilized in the peach leaves, it was in such small quantities that it did not show significant effects on color or nitrogen content of foliage, on color or time of ripening of fruit, or on terminal growth of trees.

## Literature Cited


1. Fisher, Elwood, Boynton, Damon, and Skodvin, Kaare. Fertilization of the McIntosh apple with leaf sprays of urea. *Proc. Amer. Soc. Hort. Sci.* 51: 23–32. 1948.
2. Hamilton, J. M., Palmiter, D. H., and Anderson, L. C. Preliminary tests with Uramon in foliage sprays as a means of regulating the nitrogen supply of apple trees. *Proc. Amer. Soc. Hort. Sci.* 42: 123–126. 1943.

# The Relationship of Leaf Color, Nitrogen and Rainfall to the Growth of Young Peach Trees[1]

By WESLEY P. JUDKINS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

DURING recent years fruit growers and research workers have become increasingly concerned about erosion in cultivated orchards. Because of this problem, there has been a definite trend toward less cultivation in peach orchards and in some localities sod systems have been followed. A number of reports have been published (4, 5, 6, 7, 8, 9, 10, 11, 12) which describe the results of various cultural and sod systems. In most of these experiments (4, 5, 8, 11, 12) the trees in cultivated plots made more satisfactory growth than those in sod treatments. This was especially true in the case of young trees. In some instances (6, 11) bearing age trees produced satisfactory growth and yield when the orchard was in sod.

Soil moisture and nitrogen are the factors which are most frequently limiting in orchards where peach trees are grown in sod. The experiments being reported in this paper were designed to secure additional information on the growth response of young peach trees under a sod system of managment and especially to study the influence of varying amounts of nitrogen fertilizer on such trees.

## MATERIALS AND METHODS

Halehaven peach trees were planted in the spring of 1944 and 1945 at Wooster, Ohio on a deep well-drained Wooster silt loam soil which has a moisture equivalent of 23.0 per cent and a wilting coefficient of 7.5 per cent. The trees were set approximately 21 feet apart in each direction.

*Sod Section:*—A large portion of each orchard was planted in an overwintering cover crop of rye which was not plowed at the time of planting. At that time a meadow mixture containing alsike clover, red clover, timothy, redtop and blue-grass was seeded with a disk type seeder. The land was not cultivated when the trees were set out, nor has it been plowed or cultivated since. The cover crop which developed during the first summer was rather thin but a dense bluegrass sod had become established by the third year.

Within these sod orchards randomized plots were laid out upon which different amounts of nitrogen fertilizer were applied annually. In the orchard set in 1944 these plots consist of three trees replicated three times. In the 1945 orchard the plots consist of four trees replicated three times. More replications would be desirable but space did not permit such a procedure.

The nitrogen fertilizer applications were based on the commonly recommended ¼ pound of a 20 per cent nitrogen fertilizer per year of tree age. This amount is considered as the "normal" application

[1]Journal Article No. J5–48 of the Ohio Agricultural Experiment Station, Wooster, Ohio.

and amounts to 0.05 pound of actual nitrogen per year of tree age. The following nitrogen treatments (per year of tree age) have been used on the sod plots:

0.05 pound N applied April 20
0.10 pound N applied April 20
0.10 pound N applied April 20 plus 0.10 pound N applied June 20.
0.2 pound N applied April 20
0.4 pound N applied April 20

The 0.05 pound nitrogen application was not incorporated as a treatment until the third growing season. It was expected that the presence of sod would necessitate at least a double normal nitrogen application to produce satisfactory growth. Growth responses reported in this paper illustrate that under the conditions of this experiment there was no benefit from nitrogen in excess of 0.10 pounds per year of tree age. Therefore the rates of application were changed during the third season to include a 0.05 pound treatment.

*Cultivated Section:*—Two plots of 10 trees each were set out at the same time as the trees in sod and have been maintained under a cultivation-cover crop system of management. This system consists of trashy cultivation from the middle of May until late June when a summer cover crop of soybeans is planted. In September the land is disked and a winter cover crop of rye is seeded. The trees in the cultivated plots receive 0.05 pounds of nitrogen per year of tree age, applied April 20.

The growth response of the trees was recorded annually by measuring the trunk circumference of each tree at a height of 1 foot above the surface of the soil.

The rate and amount of shoot growth was measured on representative trees during the summer of 1947.

Leaf nitrogen has been determined at several dates during the growing season by the Kjeldahl method.

Leaf color was determined by the use of a photoelectric reflection meter at the time the leaf samples were collected for nitrogen analysis.

Soil moisture was determined at irregular intervals to a depth of two feet.

## Leaf Color Versus Nitrogen Content

One of the most interesting tests employed in these experiments was the use of a photoelectric reflection meter as a means of determining leaf color. The work of Compton *et al* (1) has demonstrated the importance of leaf color and recommends its use in determining the nitrogen status in apple trees. This determination of relative nitrogen content by comparing the leaves with a color chart has limitations because everyone is color-blind, to a certain degree.

The reflection meter is an accurate and reliable instrument for determining leaf color and eliminates the need for color-matching and its inherent errors. This instrument is essentially a photoelectric cell with colored glass filters and a galvanometer with a scale from 0 to 100. Such equipment has been used for a number of years in the ce-

ramic and paint industries for determining color as well as color changes during the weathering of paints. The apparatus does not measure color directly but is a measure of reflected light. This reflectance varies with shades from light to dark and can serve as a means of measuring the intensity of the green color of leaves.

The instrument is calibrated on the basis of a fresh magnesium oxide surface having a value of 100. The reflectance readings near 100 therefore refer to an essentially white surface. Readings in the lower ranges of the galvanometer scale indicate dark surfaces with low reflectance value.

In order to determine the value of the reflection meter for measuring leaf color, peach trees were grown in gravel supplied with nutrient solutions containing different amounts of nitrogen. Five nutrient solutions were used containing 0, 10, 30, 90 and 270 parts per million of nitrogen respectively. These concentrations are within the same range as those used by other horticulturists (2, 3, 13) in similar experiments. All other essential nutrients were supplied in amounts sufficient to promote optimum growth.

The results of these tests are presented in Table I and Fig. 1, and illustrate the positive correlation between leaf nitrogen, leaf

TABLE I—LEAF COLOR, LEAF NITROGEN AND TRUNK CIRCUMFERENCE OF HALEHAVEN PEACH TREES GROWING IN GRAVEL CULTURE SUPPLIED WITH NUTRIENT SOLUTIONS CONTAINING DIFFERENT AMOUNTS OF NITROGEN

| Nitrogen in nutrient Solution (Ppm) | Total Nitrogen in Leaves* (Per Cent) | | | Leaf Color Reflectance** | | | Trunk Circumference at End of Season† (Cm) |
|---|---|---|---|---|---|---|---|
| | Jun 24 | Jul 24 | Sep 17 | Jun 24 | Jul 24 | Sep 17 | |
| 0 | 2.27 | 1.77 | 1.69 | 12.00 | 14.50 | 15.17 | 4.66 |
| 10 | 2.34 | 1.88 | 1.52 | 11.85 | 14.50 | 14.00 | 4.75 |
| 30 | 2.53 | 2.20 | 1.59 | 11.33 | 12.67 | 14.17 | 5.05 |
| 90 | 3.06 | 2.48 | 2.29 | 9.33 | 10.63 | 10 50 | 5.29 |
| 270 | 3.66 | 3.24 | 8.42 | 3.67 | 7.67 | 8.17 | 5.55 |

*Leaf samples were obtained from approximately the middle of the current season's shoots.
**Fresh magnesium oxide surface = 100.0.
†Average trunk circumference at beginning of growing season 4.4 cm.

color, and increase in circumference of trees receiving the different nutrient solutions. Such data indicate that the reflection meter is a satisfactory instrument for measuring leaf color. Positive correlations were likewise obtained between the leaf color and leaf nitrogen of trees growing under orchard conditions.

## SOD VERSUS CULTIVATION IN YOUNG PEACH ORCHARD

During the summer of 1944, following the planting of the first orchard used in this study, rainfall was below average during July, September, October and November. Even though the peach trees were located on a deep Wooster silt loam soil which is quite retentive of moisture, the growth of the young trees was retarded in the sod plots as contrasted to those in the cultivated sections. The poor growth of these trees in sod is illustrated by the solid line in Fig. 2.

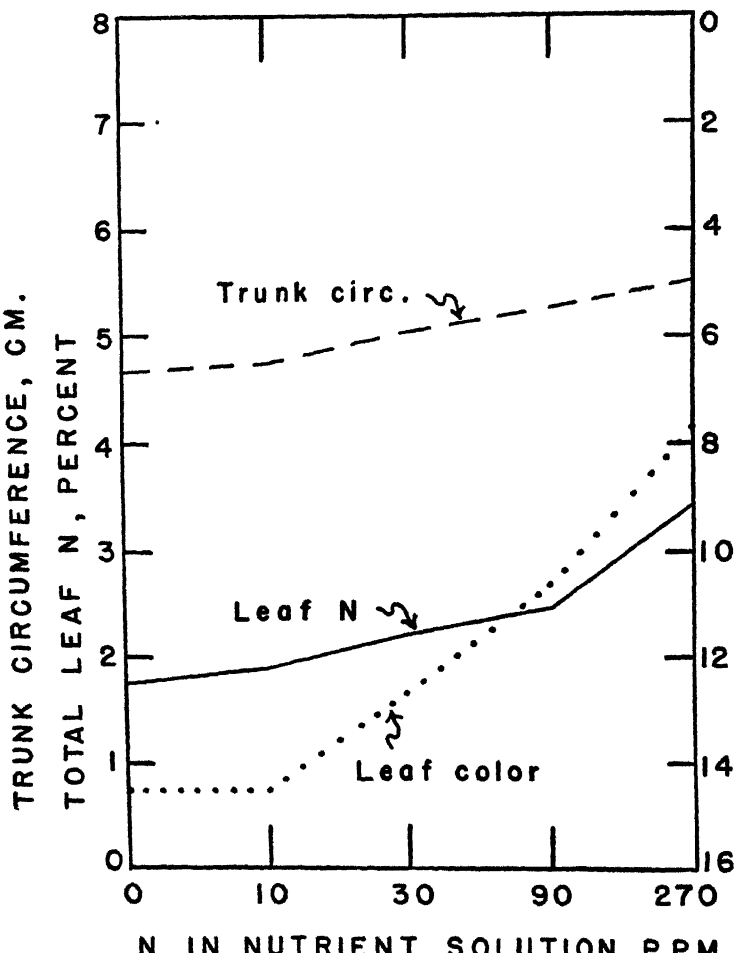


FIG. 1. Leaf color, leaf nitrogen and trunk circumference of 1-year-old peach trees growing in gravel-nutrient solution culture. Leaf color and nitrogen content were determined on July 24 on leaves from a median position of the current years shoot growth. Samples taken on June 24 and September 17 showed similar trends and correlations. The trunk circumference measurements were taken at the end of the growing season. Average circumference measurements at the start of the test were 4.4 centimeters.

During the second and third growing seasons the cultivated trees continued to grow somewhat faster than the trees in the sod plots. It would appear therefore that the suppression of growth of trees in the sod plots during the dry season of 1944 was sufficiently severe to exert a retarding influence on development for several succeeding years.

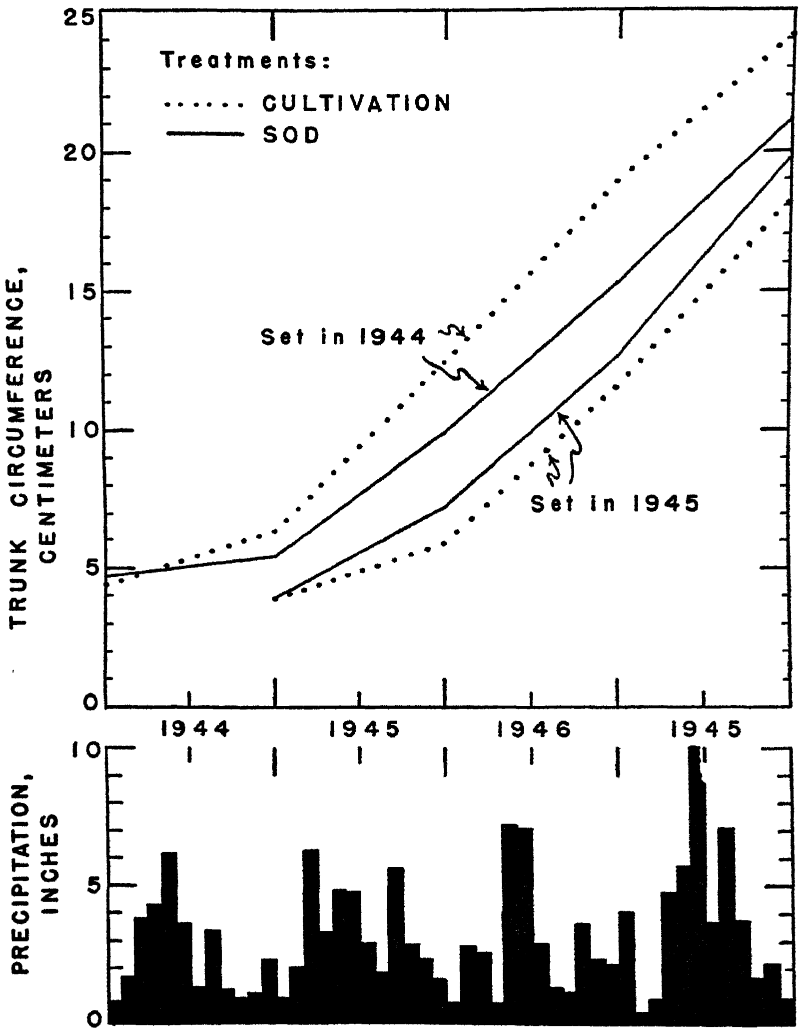


FIG. 2. Trunk circumference of young peach trees growing in cultivation with cover crops and in sod plots. The cultivated trees received 0.05 pounds of nitrogen per year of age applied April 20 each year. The trees in sod received 0.10 pound of nitrogen per year of age applied April 20. Note the poor growth of trees in sod plots in 1944 when rainfall was below average in July, September, October and November, in contrast to the good growth of 1-year-old trees in sod in 1945 when rainfall was plentiful.

A second orchard was planted in 1945 adjacent to the one discussed in the two preceeding paragraphs. Rainfall was adequate during the summer of 1945 and the trees in sod made somewhat better growth than those in the cultivated plots. Such growth re-

sponses demonstrate the importance of soil moisture during the first year after a peach tree is planted. Growth of these trees during the second and following years has been similar in the sod and cultivated sections of the orchard. During this period soil moisture has not been a limiting factor. These growth responses are illustrated in Fig. 2.

## Effect of Nitrogen Fertilization

As was indicated earlier in this paper, a number of different nitrogen treatments were applied to the peach trees in this experiment. Up to the present time there has been no difference in tree growth, as indicated by trunk circumference, between these various fertilizer treatments. Apparently nitrogen has not been a limiting factor on this silt loam soil.

Data illustrating the effect of rainfall, and fertilizer treatments on leaf nitrogen and shoot growth of peach trees in their third growing season are presented graphically in Fig. 3. The curves for

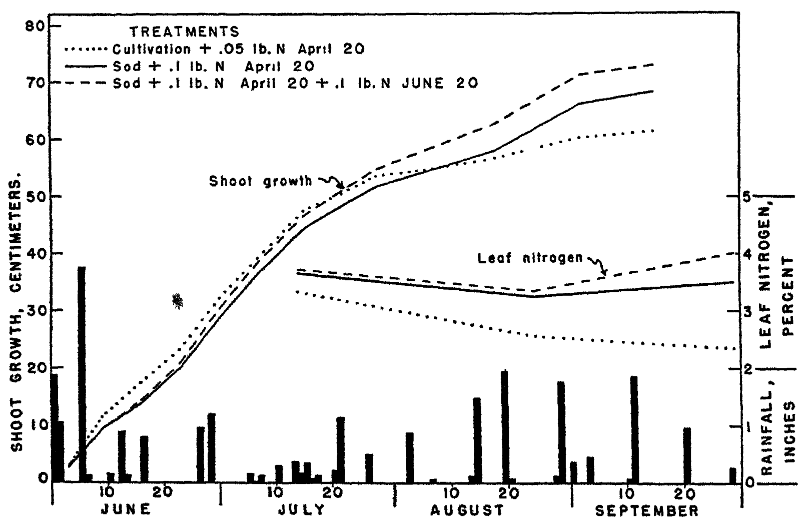


Fig. 3. Shoot growth and leaf nitrogen content of peach trees in their third growing season (1944) as influenced by nitrogen fertilization, cultural treatment and rainfall.

shoot growth illustrate the similarity in response to the various treatments.

A marked increase in growth rate can be seen in late August. This increase appears to be directly correlated with the rains which fell on August 15 and 22. Although there was no indication that the soil moisture content was approaching the wilting coefficient prior to this time, the shoot growth rate increased markedly in the sod plots following the rain. The most interesting feature of this situation is the fact that the trees in sod were influenced to a much greater

degree than those in the cultivated plots. This would seem to indicate that the moisture was much more readily absorbed in the sod plots, whereas in the cultivated plots more of the water was lost by surface runoff. Unfortunately, no soil samples were taken during this particular period and the actual change in moisture content is not known.

There was no significant correlation between leaf nitrogen and shoot growth. This indicates a lack of effectiveness of the nitrogen treatments under the conditions of this experiment.

## Summary and Conclusions

1. The color of peach leaves as determined by a photoelectric reflection meter correlated with total leaf nitrogen.
2. The photoelectric reflection meter is a satisfactory method of measuring leaf color on an accurate numerical basis. There would appear to be no reason why this instrument could not be used to measure fruit color or the color of other horticultural plant parts or products where differences in degree of color must be determined.
3. Leaf color and leaf nitrogen correlated positively with increases in circumference of 1-year-old peach trees growing in gravel-nutrient solution culture. Leaf color also correlated with leaf nitrogen content of trees growing on Wooster silt loam soil in the orchard.
4. On a deep Wooster silt loam soil, moisture was a more important factor than nitrogen in the growth of 1-year-old peach trees. The growth of trees in a sod system of management was retarded during the first year when rainfall was below average.
5. During seasons when soil moisture was not a limiting factor, Halehaven peach trees made as good growth under sod as under a cultivation-cover crop system of management during their first 3 years in the orchard.
6. During the first 3 and 4 years in the orchard, the growth of Halehaven peach trees on Wooster silt loam soil was not increased by the use of nitrogen fertilizer in excess of 0.10 pounds per year of tree age.

## Literature Cited

1. Compton, O. C., Granville, W. C., Boynton, D., and Phillips, E. S. Color standards for McIntosh apple leaves. *N. Y. (Cornell) Agr. Exp. Sta. Bul.* 824. 1946.
2. Cullinan, F. P., and Batjer, L. P. Nitrogen, phosphorus, and potassium interrelationships in young peach and apple trees. *Soil Sci.* 55: 49–60. 1943.
3. Cullinan, F. P., Scott, D. H., and Waugh, J. G. The effects of varying amounts of nitrogen, potassium, and phosphorus on the growth of young peach trees. *Proc. Amer. Soc. Hort. Sci.* 36: 61–68. 1939.
4. Cullinan, F. P., and Weinberger, J. H. Some effects of four years of cover crops in a young peach orchard. *Proc. Amer. Soc. Hort. Sci.* 34: 242–246. 1937.
5. Dunbar, C. O., Anthony, R. D., and Kinter, E. B. Peach orchard soil management. *Pa. Agr. Exp. Sta. Bul.* 476. 1945.
6. Ellenwood, C. W., and Fryman, Cecil. Peach orchard growth in sod. *Ohio Agr. Exp. Sta. Bimo. Bul.* 30: 93–95. 1945.

7. HAVIS, LEON, and CULLINAN, F. P. Second report on the effects of cover crops in a peach orchard. *Proc. Amer. Soc. Hort. Sci.* 48: 27–36. 1946.
8. HIBBARD, AUBREY D. The growth of young peach trees under different systems of soil management. *Proc. Amer. Soc. Hort. Sci.* 44: 66–70. 1944.
9. JUDKINS, W. P., and ROLLINS, H. A. The effect of sod, cultivation, and mulch treatments on soil moisture, soil nitrates, and tree growth in a young peach orchard. *Proc. Amer. Soc. Hort. Sci.* 43: 7–10. 1943.
10. JUDKINS, W. P., and WANDER, I. W. The effect of cultivation, sod and sod plus straw mulch on the growth and yield of peach trees. *Proc. Amer. Soc. Hort. Sci.* 46 · 183–186. 1945.
11. OLNEY, A. J., and ARMSTRONG, W. D. The response of peaches in Kentucky to cultivation and cover crops and to sod cultures. *Proc. Amer. Soc. Hort. Sci.* 40: 123–125. 1942.
12. SHAULIS, N. J. Tree and soil response to cultural treatments of peach orchards in south central Pennsylvania. *Proc. Amer. Soc. Hort. Sci.* 48: 1–26. 1946.
13. WALTMAN, C. S. The effect of nitrogen and phosphorus on the growth of apple and peach trees in sand culture. *Ky. Agr. Exp. Sta. Bul.* 410. 1940.

# Foliage Retention of Peach Varieties in the North Carolina Sandhills[1]

By OTTO VEERHOFF and C. N. CLAYTON, *North Carolina State College, Raleigh, N. C.*

PEACH trees in the Sandhills area of North Carolina frequently lose more than half their leaves before the end of summer. Such defoliation has been severe enough in some orchards to restrict the formation of fruit buds and the growth of terminal shoots (3). Commercial growers of this area are of the opinion that poor foliage retention is associated with low yields and loss of trees.

Major factors responsible for such premature defoliation are nitrogen deficiency, spray injury, and bacterial spot (2, 3). However, it is not unusual to observe striking contrasts in foliage retention by trees of different varieties within an orchard. In such cases, where fertilization, spray program, and exposure to bacterial spot were approximately the same for all of the trees, differences in foliage retention appeared to be a varietal characteristic. These dissimilarities may be related to varietal differences in susceptibility to spray injury (1) or possibly differences in the nutritional requirements of the varieties, which would be accentuated by the low fertility of soils of this area. However, differences in relative susceptibility to the bacterial spot organism, *Xanthomonas pruni* (E.F.S.) Dowson, appear to be more directly related to varietal differences in foliage retention. Data regarding bacterial spot susceptibility and foliage retention were obtained in three seasons on 57 varieties of peach.

These varieties were in an orchard near Eagle Springs, North Carolina, set in 1940 and 1941 on newly cleared land typical of the Sandhills area. Each variety was represented by three trees. In 1944, 1945, and 1946 the trees of each variety were rated on a scale from 1 to 10 with respect to defoliation in mid-July and at the end of August. A rating of 1 was found, by actual count of leaves of sample branches, to represent the loss of approximately 10 per cent of the leaves and a rating of 10 indicated the loss of more than 90 per cent of the leaves.

The varieties are arranged in Table I according to the average of the defoliation ratings for the 3 years, with those varieties retaining foliage best appearing first. Although the rating for a variety varied somewhat from year to year, data in the table show that this variation was small. Since arsenate of lead was omitted from the spray formula for the third year of this study, this low degree of variation from year to year indicates that differences in susceptibility to arsenical injury were not important in determining the relative order of the varieties in the table.

Observations of the foliage were made each summer to determine the relative intensity of bacterial spot infection. The average scores for

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TABLE I—DEFOLIATION AND BACTERIAL SPOT RATINGS OF PEACH VARIETIES AT THE NORTH CAROLINA SANDHILLS RESEARCH ORCHARD

| Rank No. | Variety | Degree of Defoliation in Late Summer* | | | | Bacterial Spot on Foliage** |
|---|---|---|---|---|---|---|
| | | 1944 | 1945 | 1946 | Average | Average |
| 1 | Cumberland | 2 | 2 | 1 | 1.7 | 1 |
| 2 | Mayflower | 2 | 1 | 2 | 1.7 | 1 |
| 3 | Belle of Georgia | 1 | 2 | 3 | 2.0 | 1 |
| 4 | Early Hiley | 3 | 3 | 1 | 2.3 | 2 |
| 5 | Hiley | 3 | 2 | 2 | 2.3 | 3 |
| 6 | Mikado | 3 | 2 | 2 | 2.3 | 2 |
| 7 | Hope Farm | 4 | 2 | 2 | 2.7 | 1 |
| 8 | Early Elberta | 5 | 2 | 2 | 3.0 | 2 |
| 9 | Hardee | 4 | 2 | 3 | 3.0 | 4 |
| 10 | Sunbeam | 2 | 4 | 3 | 3.0 | 1 |
| 11 | Golden Jubilee | 4 | 3 | 3 | 3.3 | 4 |
| 12 | Pioneer | 3 | 4 | 4 | 3.7 | 3 |
| 13 | Red Bird | 4 | 4 | 3 | 3.7 | 3 |
| 14 | Buttercup | 4 | 3 | 5 | 4.0 | 4 |
| 15 | Delicious | 4 | 3 | 5 | 4.0 | 3 |
| 16 | Erly-Red-Fre | 3 | 5 | 4 | 4.0 | 3 |
| 17 | Fair Beauty | 4 | 4 | 5 | 4.3 | 4 |
| 18 | Friendship | 5 | 4 | 4 | 4.3 | 4 |
| 19 | Colora | 5 | 3 | 6 | 4.7 | 3 |
| 20 | Oriole | 4 | 5 | 5 | 4.7 | 3 |
| 21 | Salberta | 5 | 5 | 4 | 4.7 | 6 |
| 22 | Gage Elberta | 6 | 5 | 4 | 5.0 | 5 |
| 23 | Raritan Rose | 5 | 5 | 5 | 5.0 | 4 |
| 24 | Marigold | 5 | 5 | 5 | 5.0 | 5 |
| 25 | South Haven | 5 | 5 | 6 | 5.3 | 5 |
| 26 | Vedette | 6 | 5 | 5 | 5.3 | 3 |
| 27 | Slappey | 5 | 5 | 6 | 5.3 | 4 |
| 28 | Midway | 5 | 6 | 5 | 5.3 | 5 |
| 29 | Eclipse | 5 | 5 | 7 | 5.7 | 2 |
| 30 | Lizzie | 6 | 5 | 6 | 5.7 | 4 |
| 31 | Rochester | 5 | 6 | 6 | 5.7 | 4 |
| 32 | Goldeneast | 6 | 6 | 6 | 6.0 | 5 |
| 33 | Elberta | 6 | 6 | 6 | 6.0 | 5 |
| 34 | Redelberta | 5 | 6 | 7 | 6.0 | 5 |
| 35 | Radiance | 6 | 6 | 6 | 6.0 | 6 |
| 36 | Redrose | 6 | 6 | 6 | 6.0 | 5 |
| 37 | Brackett | 7 | 5 | 7 | 6.3 | 4 |
| 38 | Redhaven | 6 | 7 | 7 | 6.7 | 7 |
| 39 | Golden Globe | 7 | 7 | 6 | 6.7 | 8 |
| 40 | Early Rose | 8 | 6 | 7 | 7.0 | 6 |
| 41 | Fisher | 7 | 7 | 7 | 7.0 | 6 |
| 42 | Herbhale | 7 | 8 | 6 | 7.0 | 7 |
| 43 | Valiant | 7 | 7 | 7 | 7.0 | 7 |
| 44 | Bestmay | 9 | 6 | 7 | 7.3 | 7 |
| 45 | Newday | 7 | 8 | 7 | 7.3 | 7 |
| 46 | Summercrest | 8 | 8 | 6 | 7.3 | 8 |
| 47 | Veteran | 7 | 7 | 8 | 7.3 | 7 |
| 48 | Early Halehaven | 6 | 8 | 8 | 7.3 | 8 |
| 49 | Halehaven | 7 | 8 | 8 | 7.7 | 8 |
| 50 | Triogem | 7 | 7 | 9 | 7.7 | 9 |
| 51 | White Hale | 7 | 8 | 8 | 7.7 | 8 |
| 52 | Rio Oso Gem | 9 | 7 | 8 | 8.0 | 10 |
| 53 | Sunhigh | 7 | 8 | 9 | 8.0 | 10 |
| 54 | Shippers Late Red | 8 | 8 | 9 | 8.3 | 8 |
| 55 | Primrose | 8 | 9 | 9 | 8.7 | 10 |
| 56 | Fireglow | 10 | 9 | 8 | 9.0 | 10 |
| 57 | Pacemaker | 10 | 10 | 9 | 9.7 | 10 |

*Ratings of 1 indicate slight defoliation and ratings of 10 indicate severe defoliation.
**Ratings of 1 indicate trace of infection, and ratings of 10 indicate severe infection—average for 1944, 1945 and 1946.

the 3 years of this study range from 1, for trees having only a few lesions on a very few leaves, up to 10 for trees having numerous lesions on more than half the foliage. A relationship between these ratings for bacterial spot and the defoliation ratings is evident from the table. Statistical analysis shows a correlation coefficient of +.91. This highly significant correlation between defoliation and bacterial spot indicates that differences in susceptibility of *Xanthomonas pruni* may be the

principal cause of the observed differences between varieties in respect to premature defoliation.

Whether foliage retention or bacterial spot resistance was related to flesh color was not determined. The first 16 varieties listed in the table have average defoliation ratings of 4.0 or less and constitute a group that are superior in respect to foliage retention. Although only 15 varieties in this study were of the white flesh type, 10 of them appear in this first group. It is interesting to note that the other varieties in this group, although having yellow flesh, are predominately of the pale or lemon-yellow flesh type. On the other hand, the group of varieties which showed the poorest retention of foliage are predominately of the orange-yellow flesh type. What is probably more characteristic of this latter group is similarity in genetic origin, since 12 of the last 16 varieties listed are either known or probably descendants of the J. H. Hale variety. Thus, there appears to be some relationship between the parentage of the varieties and the susceptibility to bacterial spot.

## Literature Cited

1. Blake, M. A. Peach varietal resistance to arsenical injury. *N. J. State Hort. News* 22 (3): 1307. 1941.
2. Poole, R. F. Arsenical injury of the peach and some results of studies on its control. *Proc. Amer. Soc. Hort. Sci.* 29: 42–44. 1932.
3. Williams, C. F. Nitrogen fertilization of bearing Elberta peach trees in the Sandhills. *N. C. Agr. Exp. Sta. Bul.* 322. 1939.

# Soil Structure Relations to Runoff and Erosion in a Peach Orchard[1]

By NELSON J. SHAULIS, *New York State Agricultural Experiment Station, Geneva, N. Y.*, and R. B. ALDERFER, *The Pennsylvania State College, State College, Penn.*

THIS paper is a sequel to the study (2) dealing with the effects of various cultural management practices in peach orchards on soil and water conservation by the authors in 1941. The purpose of this investigation was to study the relation between runoff and erosion in the field and several laboratory determinations of soil structure.

Li *et al* (5) report a close positive correlation of infiltration rate with probable permeability (1), stability index (1) and organic matter. That work also indicates a negative correlation of infiltration with volume weight. The soil management practice which brought high infiltration was found to foster desirable structural properties.

All the work reported here was done on the Penn shale loam of the C. E. Raffensperger farm, 8 miles northwest of Gettysburg, Pennsylvania. A brief description of the four cultural treatments studied is given in Table I. This soil is compact and susceptible to sheet erosion.

TABLE I—A BRIEF DESCRIPTION OF THE TREATMENTS AT THE TIME OF THE FIELD TRIALS

| Treatment No. | Cultural Treatment | Date of Run (1943) | Descriptive Notes | Per Cent of Soil Covered by Vegetation |
|---|---|---|---|---|
| 1 | Clean summer cultivation with sudan grass cover crop | Jun 24–26 | Complete discing on May 7 and Jun 12, 1943 | 10 |
| 1A | Crimson clover and vetch cover crop; trashy cultivated† | Jun 24–26 | Cover crop partially disced Jun 12, 1943 | 75 |
| 2C | Mixed clover sod* in 1942; cultivated in 1941 and 1943 | Jun 24–26 | Complete discing May 7 and Jun 12, 1943 | 5 |
| 2S | Mixed clover sod in 1941 and 1943; cultivated in 1942 | Jun 24–26 | Seeded to clover sod mixture Aug 4, 1942; mowed once prior to June trials | 100 |
| 3 | Mixed clover cover crop; trashy cultivated | Aug 3–9 | Mixed clovers seeded Aug 4, 1942; partially disced on Jun 12, 1943 | 50 |
| 1 | As above | Aug 3–9 | Sudan grass seeded Jul 15; very slight emergence | 5 |
| 1A | As above | Aug 3–9 | Seeded Jul 15, after complete fitting | 25 |
| 2C | As above | Aug 3–9 | Disced Jul 15, seeded Aug 3 | 5 |
| 2S | As above | Aug 3–9 | In sod, mowed after Jun trials | 90 |
| 3 | As above | Aug 3–9 | Disced Jul 15, seeded Aug 3 | 50 |

*Mixed clover sod included red, alsike, and Ladino clovers.
†Trashy cultivation is an incomplete discing or harrowing which permits much of the plant material to remain on the soil surface.

To determine the effect of such cultural practices as clean cultivation, partial or trashy cultivation of legume cover crops, alternate row cultivation and sod on soil or erosion losses, and water or runoff

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losses on two important cultural dates, a type-F rain simulator was used in the field studies of June and August 1943. A comparison of the rainfall intensities used here and those to be expected under natural conditions in this area is afforded by the work of Yarnell (8). The 1½ inches per hour intensity is equal to the 10- to 30-minute maximum intensity of many summer showers, while the 3-inch per hour intensity is the 10- to 15-minute maximum intensity of a heavy storm. The procedure in the field was the same as that described in a previous publication (2), in which the effect of soil moisture content and surface condition on runoff and erosion were considered for each experimental site. The initial rainfall application or 1½ inches per hour dry run was made on an air-dried plot surface. A second application or 1½ inches per hour wet run was made on the soil after being wetted to field capacity and the surface had become puddled depending in degree upon the particular cultural treatment. A 3-inch per hour application was made on each plot following the second 1½ inch per hour application. In June, one tree square per treatment was used, in August, the same tree square and an additional one for each treatment was used.

To determine the effect of the different cultural treatments on soil structure, samples were carefully taken of the 0–1, 1–3 and 3–6 inch surface soil layers in August from the same 6- by 12-foot areas used in the runoff trials. These samples were dried and stored for subsequent laboratory analysis. In the laboratory, the determinations of probable permeability and stability index were made according to the procedure described by Alderfer and Merkle (1). The former is a measure of the percentage of large or coarse (>0.2 mm) particles in the soil, whether they be aggregates or coarse sand or gravel. The stability index is a measure of the total amount of water-stable aggregation. Reported data are means of six determinations each. The determination of the slaking percentage was described by Shaulis (7). A 10-to 13-gram air-dried clod of soil was placed on a 3-mesh screen and immersed in a water-filled funnel revolving at 60 r p m. The volume of the column of soil slaked at 6 minutes was expressed as a percentage of the volume of the column when all of the soil was stirred through the screen after 6 minutes. Each slaking percentage is the mean calculated from 22 clods of soil.

## Runoff and Erosion Measurements

Fig. 1A shows the runoff hydrographs for the initial or dry soil runs in 1 hour June trials and Fig. 1B those for the August trials. Table II presents the means of the data for the various treatments on soil structural measurements as well as the runoff and erosion measurements during the June and August trials. The water loss figures in Table II for both June and August conditions show the usual relationship of less runoff and a longer period of time to reach equilibrium runoff in a dry soil than in one recently wetted where the surface has been puddled to some degree.

*Results of the June Field Trials:*—Clean cultivation, treatment 1, the conventional peach orchard soil management practice, rendered

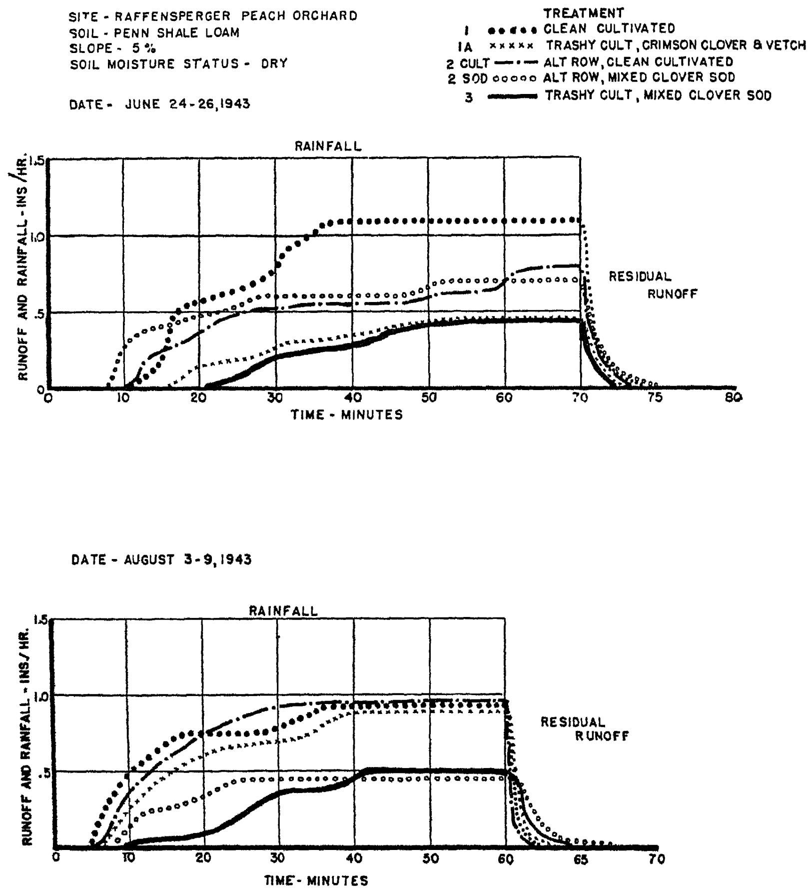



FIG. 1A (above) and 1B (below)—Runoff hydrograph, showing the rate of water loss from differently treated Penn shale loam during a 1½-inch per hour rain.

the soil most susceptible to both runoff and erosion. Treatment 2 cultivated, in which the soil had been in undisturbed clover sod the year before, showed the beneficial residual effects of this previous treatment during the initial or dry run in reduced runoff losses but, after the surface had become puddled by the beating or dispersing action of the raindrops, its behavior became almost identical to that of the continuous clean cultivation treatment.

Trashy cultivation, treatments 1A and 3, in which a considerable portion of the soil surface was left covered with dead or growing vegetation was very effective in reducing both soil and water losses. The difference between these two trashy cultivated treatments was that all of the crimson clover and vetch had been killed and was left either on the surface or partly buried as a surface mulch, whereas, in

TABLE II—SUMMARY OF SOME SOIL CHARACTERISTICS AND OF RUNOFF AND EROSION LOSSES (RAFFENSPERGER ORCHARD, 1943)

| Treatment No. | Soil Structural Measurements: Soil Depth (Ins) | Per Cent Slaking | Probable Permeability | Rainfall Intensity and Soil Moisture Condition [Inches/hr.] | Runoff and Erosion Measurements — Runoff: Per Cent of Total Rainfall Lost during Various Time Periods — June Trials (Time in Minutes) 15 | 30 | 45 | 60 | August Trials (Time in Minutes) 15 | 30 | 45 | 60 | Erosion: Lbs Soil Lost Per Cu Ft of Runoff — June | Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Clean Cultivated* | | | | | | | | | | |
| 1 | 0–1 | 72 | 33.7 | 1½/hr dry | 2 | 17 | 32 | 42 | 18 | 34 | 42 | 47 | 0.46 | 0.75 |
| | 1–3 | 61 | 35.0 | 1½/hr wet | 50 | 64 | 68 | 71 | 69 | 75 | 78 | 80 | 0.62 | 0.67 |
| | 3–6 | 37 | 39 0 | 3/hr wet | 47 | 52 | 53 | 55 | 48 | 53 | 55 | 56 | 1.09 | 1.44 |
| | | | | *Crimson Clover and Vetch, Trashy Cultivated* | | | | | | | | | | |
| 1A | 0–1 | 14 | 40.5 | 1½/hr dry | 0 | 5 | 8 | 14 | 11 | 26 | 35 | 41 | 0.00 | 0.66 |
| | 1–3 | 25 | 39.2 | 1½/hr wet | 15 | 29 | 34 | 37 | 42 | 57 | 63 | 65 | 0.05 | 0.35 |
| | 3–6 | 25 | 43.2 | 3/hr wet | 36 | 43 | 47 | 50 | 44 | 48 | 50 | 51 | 0.04 | 0.86 |
| | | | | *Alternate Row Cultivated* | | | | | | | | | | |
| 2 | 0–1 | 53 | 45.5 | 1½/hr dry | 4 | 15 | 19 | 24 | 15 | 31 | 42 | 47 | 0.52 | 1.04 |
| | 1–3 | 30 | 47.4 | 1½/hr wet | 60 | 65 | 67 | 68 | 53 | 64 | 68 | 70 | 0.32 | 0.70 |
| | 3–6 | 8 | 45.1 | 3/hr wet | 42 | 45 | 48 | 51 | 45 | 51 | 53 | 54 | 0.47 | 0.85 |
| | | | | *Alternate Row Sod-mixed Clover* | | | | | | | | | | |
| 2 | 0–1 | 4 | 53.8 | 1½/hr dry | 10 | 22 | 27 | 32 | 4 | 15 | 20 | 22 | 0.00 | 0.00 |
| | 1–3 | 9 | 54.5 | 1½/hr wet | 27 | 45 | 50 | 53 | 15 | 28 | 32 | 35 | 0.00 | 0.00 |
| | 3–6 | 19 | 43.5 | 3/hr wet | 32 | 39 | 41 | 42 | 32 | 39 | 42 | 45 | 0.00 | 0.00 |
| | | | | *Mixed Clover—Trashy Cultivated* | | | | | | | | | | |
| 3 | 0–1 | 37 | 43.9 | 1½/hr dry | 0 | 3 | 7 | 10 | 1 | 7 | 14 | 19 | 0.19 | 0.40 |
| | 1–3 | 11 | 46.5 | 1½/hr wet | 20 | 35 | 43 | 48 | 24 | 36 | 39 | 41 | 0.16 | 0.43 |
| | 3–6 | 17 | 40.2 | 3/hr wet | 28 | 36 | 39 | 40 | 29 | 37 | 39 | 41 | 0.31 | 0.45 |

the trashy cultivated mixed clover sod only a portion of the vegetation had actually been killed, thus leaving a partial surface covering of both living and dead legumes.

Runoff from the alternate rows that had been left in mixed clover sod, treatment 2 sod, was greater than would normally be expected from an area having an excellent vegetative canopy. Inspection of the soil conditions beneath this legume sod revealed that the surface remained smooth and firm to the point of compaction, which condition was undoubtedly accentuated by the compacting effects of normal orchard machinery traffic over all of these plots, while the soil was wet during the spring months.

Soil or erosion losses from the differently treated plots varied with the amount of surface protection each treatment afforded at this particular time of the year.

Trashy cultivated crimson clover and vetch was the outstanding single cultural treatment in its controlling effect on runoff and erosion losses in the June trials. The combined effects of having alternate tier rows in sod and clean cultivation should be considered in a practical evaluation of the treatment.

*Results of the August Field Trials:*—As indicated in Table I, all of the plots, except the mixed clover sod in treatment 2, had been

fitted and seeded since the June trials. The runoff and erosion data, Table II, show that additional cultivation together with fitting for a new cover crop seeding had increased the susceptibility of the soil to runoff and erosion.

The greatest increase in runoff and erosion occurred under the trashy cultivated crimson clover and vetch treatment where the surface mass of plant residue was replaced by a bare cultipacked seedbed. Soil losses from the other cultivation treatments were roughly twice those for the June trials. The undisturbed mixed clover sod in treatment 2 remained effective in its complete control of erosion losses. This was the only treatment in which a reduction in runoff was recorded. Runoff from all other treatments, Nos. 1, 2 cultivated and 3 was about that measured in the June trials, except for the first 30 minutes of the initial or dry August runs, where runoff losses were much greater in August than they were in June for each of these treatments.

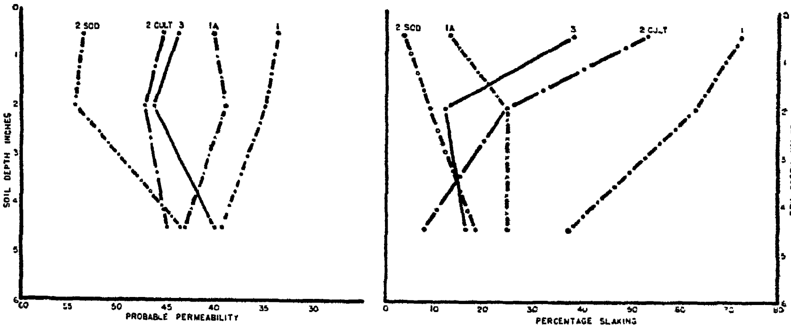
The differences in the behavior of this soil under these cultural treatments with respect to runoff and erosion were caused by many factors. Important ones were, variations in the protection afforded the soil surface by dead or growing vegetation, variations in micro relief or the roughness of the soil surface, wide differences in soil moisture, and variations in the soil structure. These latter differences were considered in the laboratory studies.

## Soil Structure Measurements

The data concerning the probable permeability of this Penn shale loam are presented in Table II and Fig. 2A; those for the slaking percentage are in Table II and Fig. 2B. In each, the effect of the tillage or vegetative cover was most apparent in the surface inch and was smallest at the 3- to 6-inch depth. In connection with Figs. 2A and 2B, the statistical significance of the graphed means is shown.

The stability index was the least sensitive in describing the structural stability of the soil. The range of the means was about one-half that for the means of probable permeability. The data for it are not presented. That this was not a useful criterion here, was taken to mean that the treatments did not differ much in their effect on the amount of soil aggregated, but rather in their effect on the number of larger water-stable soil granules which in turn affects the noncapillary porosity of the soil upon which the infiltration rate depends, The probable permeability data, in Table II, indicate a rather close relationship between the length of time this soil had been in sod or free from mechanical disturbances and its structural condition as reflected in the size and frequency of the water-stable aggregates produced. Treatment 1, clean cultivation, and treatment 2, mixed clover sod, represent the extremes in this case with the other treatments being intermediate.

When it is recalled the treatment 2 sod in 1943 and 1941 was treatment 2 cultivated in 1940 and 1942, it is not surprising that the structure of the surface was more water-stable than that of the sub-surface soil. The sod and the residue were concentrated at the surface. The




FIGS. 2A (left) and 2B (right)—Effect of different cultural treatments on the structure of Penn shale loam surface soil.

Statistical Significance of Differences Between Graphed Means

| Soil Depth | Probable Permeability: Highly Significant | Probable Permeability: Significant | Slaking Percentage: Highly Significant | Slaking Percentage: Significant |
|---|---|---|---|---|
| 0 to 1 inch | 1-1A, 2 cult., 3<br>1-2 sod.<br>1A-2 sod. | 3-2 sod. | 1-1A, 2 sod, 3.<br>2 cult.-1A, 2 sod, 3.<br>1A-2 sod.<br>3-2 sod. | 1-2 cult. |
| 1 to 3 inches | 1-2 cult., 3.<br>1-2 sod.<br>1A-2 sod.<br>3-2 sod. | 1A-2 cult., 3 | 1-2 cult., 3, 1A.<br>1-2 sod.<br>1A-2 sod.<br>3-1A. | None |
| 3 to 6 inches | None | None | 1-2 sod, 3, 2 cult.<br>1A-2 cult.<br>2 sod.-2 cult.<br>3-2 cult. | 3-1A. |

surface soil of treatment 2 cultivated is less water-stable than the sub-surface which had been made more water-stable by the sod grown on this plot in 1942.

The structure of the upper layer of surface soil in treatment 1 as measured by these two methods, was inferior to that of the sub-surface soil layers. This soil had the least vegetative cover and the most tillage of any treatments reported here.

The ranges in the values for the probable permeability and stability index were not large; most of the dispersion of the values could be assigned to variation between sites. In these analyses a 50-gram sample of soil screened through a 4 mm sieve was used. For the slaking samples, individual clods of soil at field structure were used and the variability was great. It was greatest for treatment 2 cultivated (where there was both recently tilled soil and sod fragments) and was higher for the 1- to 3-inch sampling than the 0- to 1-inch sampling. The differences between treatments, too, were large so that this technique was usable in describing the slaking tendency of the soil in the various plots.

## Relation of Structural Measurements to Runoff and Erosion

Table III shows the relation between soil structure and runoff and erosion measurements. The results for both the 1½-inch per hour

applications on the dry and wetted surface are used. There would be no change in the relative positions of any of the plots, if either the wet or dry trial data were used separately. Peele *et al* (6) report that data from dry runs give better correlation with results from natural storms than data from the wet runs. According to the data contained in Table III, there is a general agreement between the two methods in separating the treatments which rendered this soil susceptible to high as contrasted with low runoff and erosion losses. These differences hold even for the individual sites within a treatment as shown in Table III.

TABLE III—Variability in Runoff and Erosion and Soil Structure in Replicate Sites Among the Various Treatments (Based on the Data, Obtained From the 1½ Inch per Hour Rainfall Application on Dry and Wet Soil in August 1943)

| | Soil Moisture | Treatments | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 1A | | 2 Cult | | 2 Sod | | 3 | |
| | | Site | | | | | | | | | |
| | | I | II | I | II | I | II | I | II | I | II |
| Soil loss in pounds per cubic foot runoff at maximum equilibrium runoff | Dry | 0.42 | 1.08 | 0.34 | 0.48 | 1 27 | 0.81 | 0.0 | 0.0 | 0 50 | 0.31 |
| | Wet | 0.65 | 0.69 | 0.20 | 0 50 | 0.77 | 0.62 | 0.0 | 0.0 | 0.45 | 0.40 |
| Average runoff as per cent of applied rain for a 60-minute period | Dry | 39 | 55 | 33 | 49 | 56 | 39 | 23 | 21 | 25 | 15 |
| | Wet | 85 | 75 | 59 | 69 | 72 | 68 | 40 | 30 | 45 | 34 |
| Soil slaking mean at 0 to 1-inch | | 82 | 62 | 10 | 18 | 68 | 38 | 5 | 3 | 39 | 36 |
| Probable permeability. Mean at 0 to 1 inch | | 33.2 | 34 3 | 39.6 | 41 4 | 45.7 | 45.4 | 50.3 | 57.3 | 41.8 | 45.9 |

The association between soil structure and runoff and erosion based on these field and laboratory data, is shown by the following correlation coefficients:

| | Soil Loss (Erosion) Dry Run | Soil Loss (Erosion) Wet Run | Water Loss (Runoff) Dry Run | Water Loss (Runoff) Wet Run |
|---|---|---|---|---|
| | r | r | r | r |
| Slaking | 0.701±0.252 | 0.876±0.170** | 0.553±0.093 | 0.724±0.244* |
| Probable permeability | −0.456±0.318 | −0.653±0.268* | −0.766±0.146** | −0.786±0.218** |

*Significant, **Highly significant.

Probable permeability is a more reliable characterization of the infiltration capacity of the soil than it is of its erodibility. Probable permeability determinations of the 0- to 1-inch layers of surface soil from the different treatment sites were found to agree quite closely with their actual permeability. Free *et al* (4) report that all indices of large pores or those factors affecting pore size were definitely associated with infiltration when all vegetation was removed from the surface of 68 soils. Probable permeability, which is a measure of the percentage of a given soil consisting of large soil particles, which directly affects the percentage of large soil pores would be in this group.

The slaking percentage would be considered to indicate the structural stability of the soil and thus the permanency of the larger soil pores. Slaking percentage was most closely associated with the erodibility of this soil.

Because of such additional variables as surface roughness, low moisture content and surface protection, runoff and erosion losses during the initial or dry run showed the least correlation with laboratory measurements of soil structure.

Surface roughness, which exerted its greatest effect in the trashy cultivated treatments, accounted for a marked reduction in runoff and erosion, particularly during the first 15 to 30 minutes of the initial or dry run. Peele *et al* (6) and Duley and Kelly (3) present data to show that surface cover was of the greatest importance in affecting control of runoff and erosion. It is obvious that treatment 2 sod, which had the most compete vegetative cover, is in direct contrast, so far as field and laboratory data are concerned, with treatment 1. which had the least cover. Surface protection appears to be especially important in the control of soil erosion. Considering the mixed clover sod and clean cultivated treatment as extremes, the erosion data presented here show that erosion losses are very intimately associated with the degree of cover afforded the soil surface.

TABLE IV—The Relation Between Runoff Rate and Soil Cover in Peach Orchard Cover Crop Plots (Raffensperger Orchard 1941–1943)

| Per Cent Soil Cover* | Per Cent Runoff at Maximum Equilibrium Rate during 1½Inch Wet Run | | | | |
|---|---|---|---|---|---|
| | Treatment | | | | |
| | No. 1 | No. 1A | No. 2 Cultivated | No. 2 Sod | No. 3 |
| 0–20 | 90, 75, 85 | 70 | 70, 75 | | |
| 20–40 | — | 70 | — | — | — |
| 40–60 | — | — | — | — | — |
| 60–80 | 70 | — | 85 | — | 55, 50 |
| 80–100 | — | 40, 45 | 70 | 45, 60, 80 | 30 |

*Field estimates were made to the nearest 5 per cent; these five groups are arbitrarily taken.

A closer study of these data as well as those obtained in 1941 and 1942 (2) shows that the control of runoff in the soil is not simply a matter of the amount of vegetative cover. Table IV presents the runoff data, at the equilibrium rate for the 1½-inch wet runs, for all such runs made during 1941 to 1943.

When these data are plotted, it is readily seen that treatments 1 and 2 cultivated show little reduction in runoff with increases in the amount of ground cover. Treatments 1A and 3 do have a reduced runoff when the ground cover is increased. The runoff from treatment 2 sod is highly variable with 80 per cent or more of the soil covered by a legume sod. It was observed that the high runoff occurred in treatment 2 sod when the soil surface was smooth because of the fitting at seeding time, the crusting of the soil surface before and during the seedling stage of the seeded clovers and when the surface had been compacted by ordinary orchard traffic. Runoff occurring in the presence of a high amount of cover carried little or no soil.

## Summary and Conclusions

The runoff and erosion data obtained in 1943 from these peach orchard cultural plots are in full agreement with those obtained in previous years.

Associated with the increase in the runoff and erosion control in those treatments with the most continuous sod cover was an increase in the proportions of effectively large soil particles and in the re-

sistance to slaking. These two laboratory procedures afford a definition of soil structure which is associated with the infiltration capacity of the soil. The amount of ground cover and/or the data from the rain simulator would likely be of more value in predicting the actual amount of erosion under natural conditions than would the measures of soil structure used here.

On the basis of field observations and a statistical analysis of water (runoff) and soil (erosion) losses and soil structure measurements, probable permeability was most closely associated with infiltration capacity and to a lesser extent with erodibility, whereas the reverse appeared to hold for the slaking value.

The results of this study illustrate the need for the combined effects of good soil structure, surface protection and surface roughness in achieving maximum protection against runoff and erosion.

## Literature Cited

1. Alderfer, R. B., and Merkle, F. G. The measurement of structural stability and permeability and the influence of soil treatments upon these properties. *Soil Sci.* 51: 201–212. 1941.
2. Alderfer, R. B., and Shaulis, Nelson J. Some effects of cover crops in peach orchards on runoff and erosion. *Proc. Amer. Soc. Hort. Sci.* 42: 21–29. 1943.
3. Duley, F. L., and Kelly, L. L. Effect of soil type, slope, and surface conditions on intake of water. *Neb. Agr. Exp. Sta. Res. Bul.* 112. 1939.
4. Free, G. R., Browning, G. M., and Musgrave, G. W. Relative infiltration and related physical characteristics of certain soils. *U. S. D. A. Tech. Bul.* 729. 1940.
5. Li, Lai Yung, Anthony, R. D., and Merkle, F. G. Influence of orchard soil management upon the infiltration of water and some related physical characteristics of the soil. *Soil Sci.* 53: 65–74. 1942.
6. Peele, T. C., Latham, Earle E., and Beale, O. W. Relation of the physical properties of different soil types to erodibility. *So. Car. Bul.* 357. 1945.
7. Shaulis, Nelson J. Tree and soil response to cultural treatments of peach orchards in South Central Pennsylvania. *Proc. Amer. Soc. Hort. Sci.* 48: 1–26. 1946.
8. Yarnell, David L. Rainfall intensity frequency data. *U. S. D. A. Misc. Pub.* 204. 1935.

# The Effect of Nitrogen on Nonirrigated Prunes

By E. L. PROEBSTING, *University of California, Davis, Calif.*

VERY LITTLE information is available on the response of fruit trees to nitrogen under conditions of inadequate moisture supply. Trials with almonds (1) showed increased yield and better tree performance of fertilized trees compared with unfertilized checks. The assumption made at the beginning of these trials that a better nitrogen supply while water was still available would increase the vegetative growth, proved to be correct. The further assumption that this increased leaf surface would use the water stored in the soil at a faster rate and that the trees would suffer from the stress of depleted soil moisture for a longer period in the fall proved not to be correct. The almond fruit develops its edible portion, the seed, to full size early in the season. Food storage in the cotyledons continues over a prolonged period, giving time for complete filling of the seed coat.

In contrast, the other stone fruits receive a large share of their reserve material in the flesh during the stage of final swell just before maturity. It was to determine whether or not this final development would be affected, as well as to see the effect on the tree condition, that trials were started in 1940 in a nonirrigated French prune orchard near Vacaville, California. The orchard lies on a slope. The soil is a Hugo clay loam. This is a residual soil underlain with sedimentary rock, usually less than 30 inches in depth. The field capacity of this soil is about 28 to 30 per cent, and the permanent wilting percentage about 12 to 16 per cent. Rainfall averages about 26 inches, falling almost entirely between October and May. About 7 inches could be retained at field capacity.

Two nitrogen sources were used, ammonium sulfate and anhydrous ammonia. The former was broadcast in a circle about the tree and the latter was injected to an average depth of 5 inches. The equipment used for injection at the beginning was an experimental tool built by the Shell Development Company mounting a (single) cylinder of ammonia and delivering it at a pre-determined rate behind a set of three subsoiler shoes. A V-crowder behind each shoe sealed over the small furrow. This method, which was improved with the years, worked very well when the soil was properly prepared, but difficulties were encountered when the mulch was trashy or cloddy. The applications were made in late fall, but before the winter rains interfered. It was found that air-dry soil was capable of holding ammonia with negligible loss. One pound of nitrogen per tree per year was the rate of application.

The trees showed the effects of inadequate moisture. There were many missing trees, as is evident from an air view (Fig. 1). The trees were not producing well and the fruit was small, with a good deal of sunburn. These conditions were chosen deliberately to see whether the trees could be brought back. Plots consisted of two rows the length of the orchard, normally 25 trees.

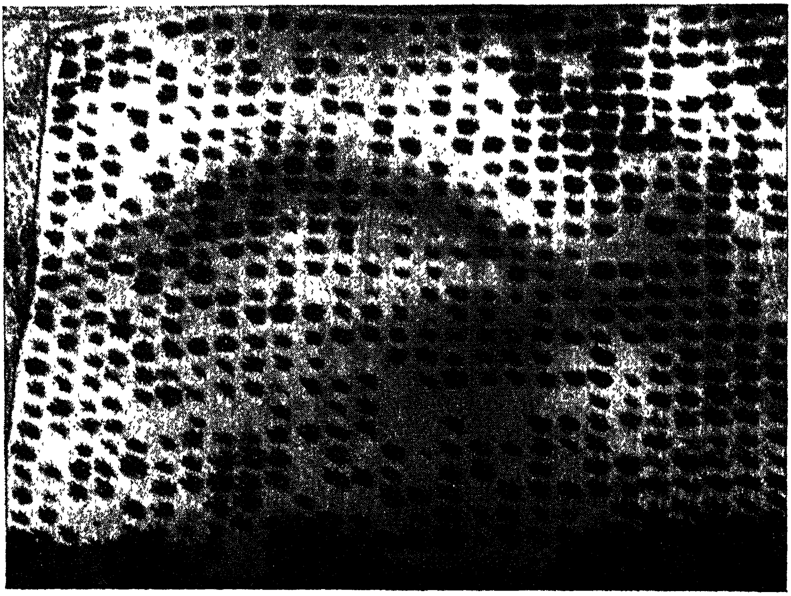


Fig. 1. Air view of orchard (1940)

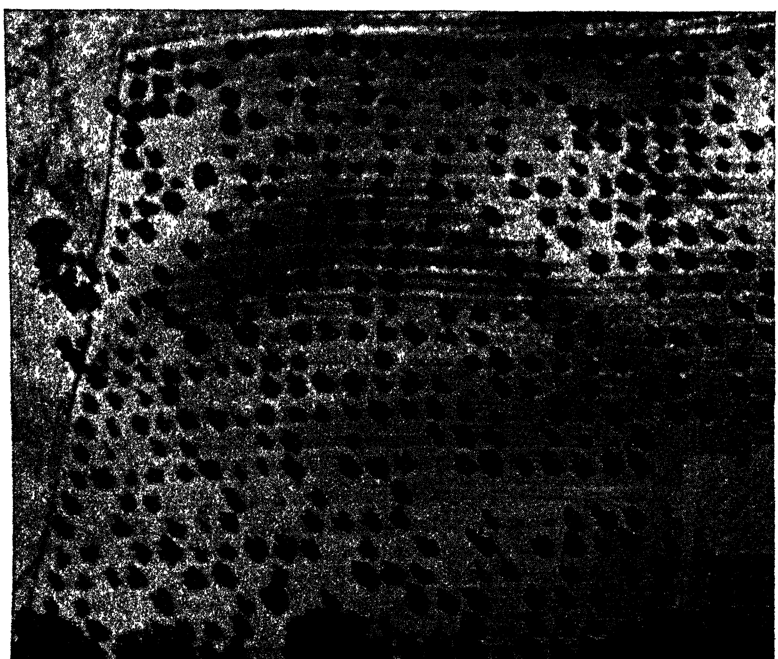


Fig. 2. Air view of orchard (1946)

Treatments were in triplicate with unfertilized checks between treatments. The plots in order ascending the slope were: $NH_3$, check, $(NH_4)_2SO_4$, check, $(NH_4)_2SO_4$, check, $NH_3$, check, $NH_3$, check, $(NH_4)_2SO_4$.

Accurate yield records were not kept, but estimates of crop and of tree condition were made each year before harvest. Tree condition was represented on a scale of 1 (best) to 5 (barely alive). Vigor, amount of die back and leaf color but not size of tree were factors used. Leaf samples were taken at intervals to determine nitrogen status. Some soil samples were taken to follow nitrification, but technical difficulties prevented their satisfactory untilization.

Examples of trees in different categories of condition were photographed annually to show graphically the progressive changes during the experiment. A check tree which was originally a class 1 is shown in successive stages of deterioration (Figs 3, 4, 5). Another tree, fertilized, is shown in Figs. 6, 7, 8. Another air view (Fig. 2) taken in 1946 shows the change in orchard appearance. The southwestern corner of the orchard was severely damaged by excessive water in the wet winter of 1941–42. Drainage from the slope into this area caused prolonged soil saturation. Fortunately, most of this area lay south of the experimental area, but plots 3, 4 and 5 lost 6, 9 and 4 trees respectively.

At the beginning of the experiment there was no significant difference in tree condition over the block except that the trees at the western edge were superior. These trees were excluded from treatment. The average tree condition was 3.2. The average at the end of 1948 was 2.2. Some of this improvement was due to the death of

FIG. 3. Check tree (October, 1940) example of class I

FIG. 4. Check tree same as FIG. 3 (October, 1943) tree in class II

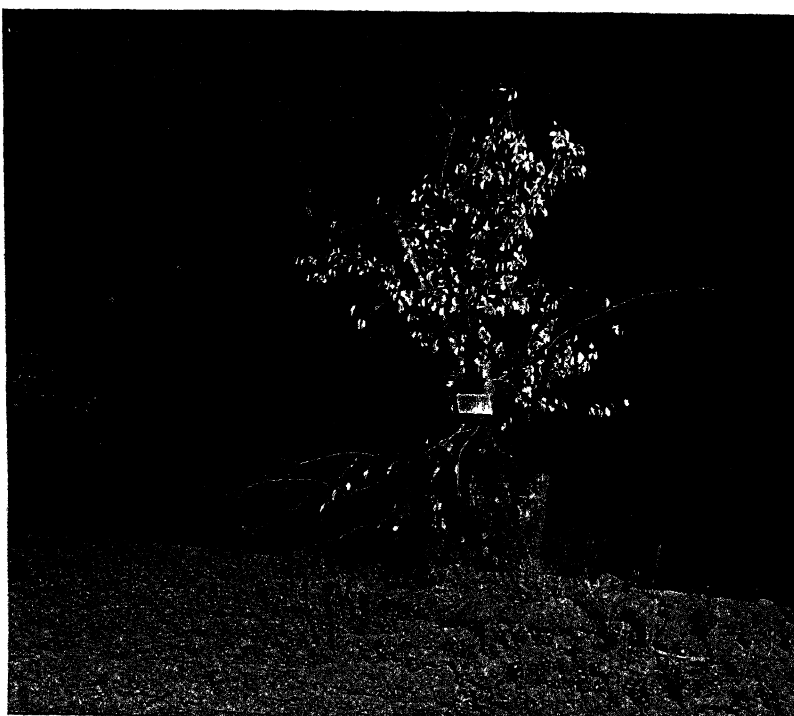


FIG. 5. Check tree same as FIG. 3 (October, 1948) tree in class V

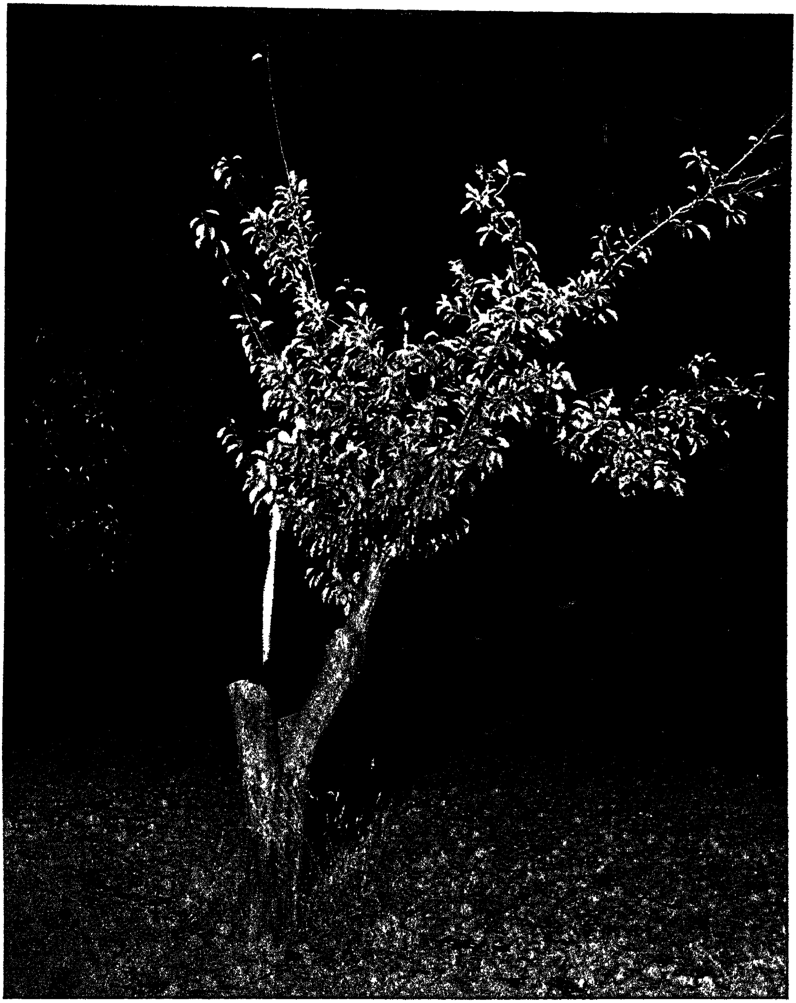


FIG. 6. Fertilized tree (October, 1940) example of class V

class 4 and 5 trees. Some was due to a series of years climatically favorable for these trees. Some was due to the nitrogen, the treated trees averaging 1.9 and the check trees 2.4, a significant difference. A few trees that showed response to nitrogen during the period of treatment died from other causes. For example, a tree chosen as an example of class 5 condition at the beginning of the period improved to class 1 in 1948 (Figs. 6, 7, 8), but at harvest time collapsed due to heart rot. There was too little sound wood remaining to support the weight of new growth and fruit.

Another indication of the effect of nitrogen on condition is the

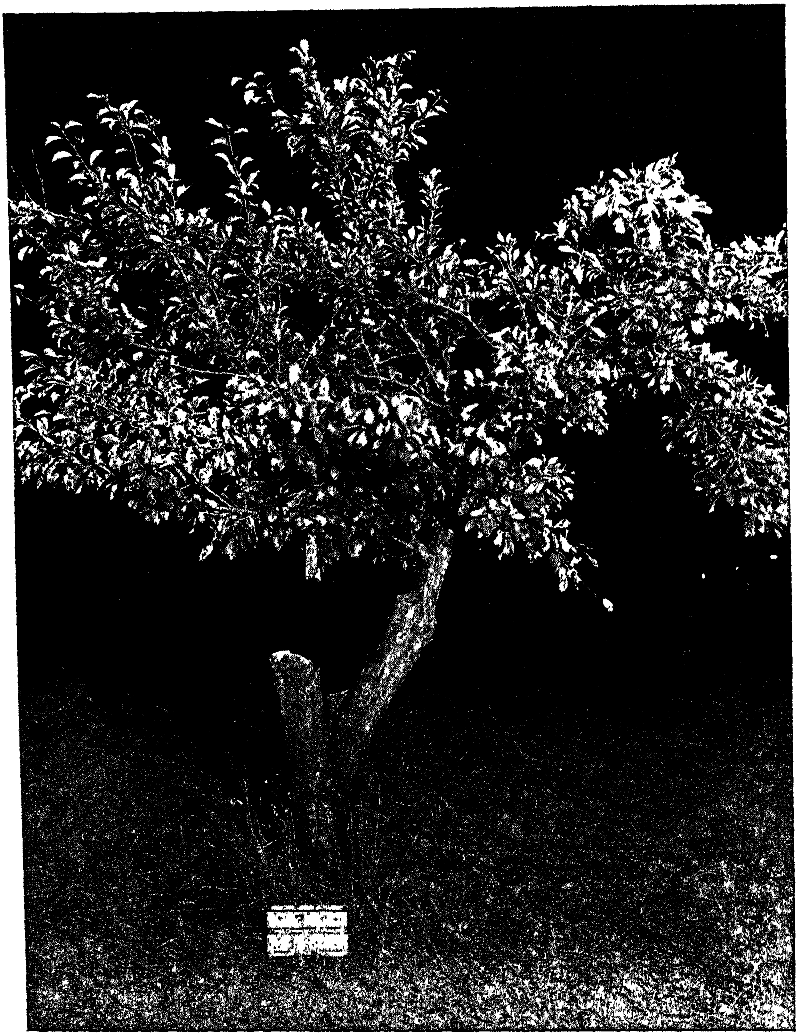


FIG. 7. Fertilized tree same as FIG. 6 (October, 1943) tree in class II

fact that 39 per cent of the trees in the check plots had a lower rating in 1948 than in 1940. Only 27 per cent of the treated trees showed a lower rating. Trees which died from any cause were included in these percentages. If the dead trees are eliminated from the calculation, the check trees show 12 per cent with a lower rating and the fertilized, 4 per cent.

Yield records have little significance in such a variable orchard. However, to show the general trend, the results are indicated in Table I, the figures having been arrived at by independent estimates

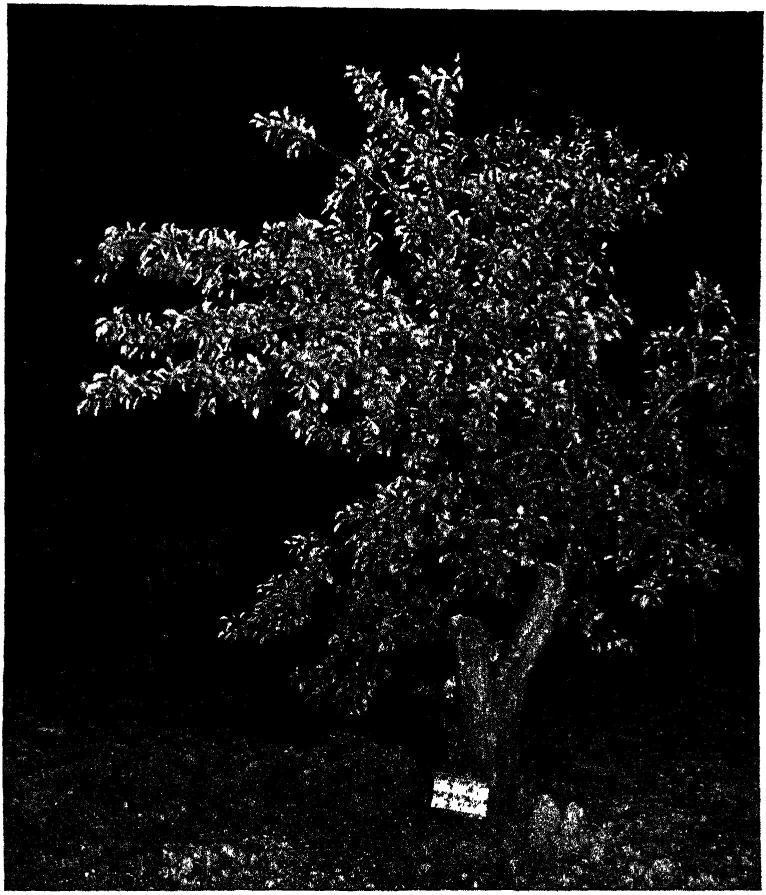


FIG. 8. Fertilized tree same as FIG. 6 (October, 1947) tree in class I

by at least two staff members familiar with prunes. A gradual improvement in the relative yields of the fertilized trees is evident. No fruit was graded, but the fruit on the fertilized trees was observed to be somewhat larger than that on the check trees.

Data were obtained each year showing total nitrogen of leaves for each plot. The first year showed no difference in nitrogen content. Thereafter, the average for the check plots was lower than for the fertilized plots. There has been no consistent difference between those plots receiving $NH_3$ and those receiving $(NH_4)_2SO_4$. In most years, the curves from the data were approximately straight lines although the slopes varied from year to year. In 1941 and 1947 different patterns were observed. There was a displacement of the time a given concentration would be reached depending on the season.

TABLE I—PRUNE YIELD IN POUNDS PER TREE

| Plot | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | $NH_3$ | Check | $(NH_4)_2SO_4$ | Check | $(NH_4)_2SO_4$ | Check | $NH_3$ | Check | $NH_3$ | Check | $(NH_4)_2SO_4$ |
| 1941........ | 37 | 29 | 24 | 23 | 27 | 30 | 43 | 35 | 43 | 35 | 43 |
| 1942........ | 58 | 69 | 59 | 72 | 62 | 59 | 66 | 72 | 55 | 61 | 53 |
| 1943........ | 98 | 98 | 118 | 81 | 93 | 84 | 112 | 121 | 109 | 115 | 131 |
| 1944........ | 50 | 65 | 67 | 39 | 47 | 45 | 55 | 54 | 53 | 45 | 55 |
| 1945........ | 30 | 21 | 36 | 16 | 25 | 18 | 26 | 24 | 24 | 21 | 29 |
| 1948........ | 77 | 80 | 120 | 66 | 91 | 69 | 99 | 73 | 90 | 80 | 100 |

## SUMMARY

1. Prunes in a nitrogen deficient status can show marked response to nitrogen fertilizer in both tree condition and yield even where water becomes deficient before the full maturity of the crop.

2. Application of anhydrous ammonia by dry injection in the soil has been about as effective as ammonium sulfate.

3. Leaf analyses show slightly different seasonal patterns from year to year. These curves illustrate the usefulness of leaf analyses in plot interpretation and the difficulty of using them alone for diagnostic purposes.

## LITERATURE CITED

1. PROEBSTING, E. L. Field and laboratory studies on the behavior of $NH_4$ fertilizer with special reference to the almond. *Proc. Amer. Soc. Hort. Sci.* 33:46–50. 1935.

# Some Effects of Nitrogen Fertilizer on Yield and Maturity of Elberta Peaches

By J. H. Weinberger, *U. S. Department of Agriculture, Fort Valley, Ga.*

In south-central Georgia and other early shipping areas, the earliest ripening fruit of any particular variety usually brings the highest prices. On this account peach growers adapt their orchard practices to cause the fruit to ripen as early as possible. One method of advancing maturity is to withhold nitrogen fertilizer, or to apply only small amounts of nitrogen. The present study was initiated to determine whether certain nitrogen carriers differed in their effects on the maturity and yield of the fruit, and the relative effects of spring, after-harvest, and fall application of nitrogen fertilizer under Georgia conditions.

Investigators are in agreement that the use of nitrogen fertilizer on peach trees delays maturity of the fruit. In central Georgia (1) there was approximately a 1-day delay in maturity with each .1 pound of nitrogen applied per tree. It has been shown also that fall applications of nitrate of soda did not stimulate growth as much as spring applications (2), but with ammonium sulfate and calcium cyanamide time of application had little effect. Williams (3) has shown that under conditions in the Sandhill section of North Carolina postharvest applications of nitrate of soda increased terminal growth in comparison with spring applications.

## Methods

Three nitrogen carriers were used — nitrate of soda, ammonium sulfate, and cottonseed meal. All are commonly applied to commercial peach orchards, the ammonium sulfate principally in mixed fertilizers.

The trees selected for the experiment were part of a 50-acre Elberta orchard planted in the spring of 1937, near Fort Valley, Georgia. The soil is a Magnolia fine sandy loam, with practically no slope. The pH of the top foot of soil at the conclusion of the experiment averaged 6.0 ± .1 for all treatments except ammonium sulfate. The latter reduced the pH to 5.5. The trees were planted 18 feet apart and every fourth tree in every fourth row was a pecan tree. A plot consisted of nine trees, arranged in a square. Pecan tree rows were buffer rows between plots. Treatments consisted of check (no nitrogen); nitrate of soda applied (a) after harvest, (b) in the fall, (c) in the spring about 2 weeks before bloom, (d) 2 weeks after bloom, (e) in the spring without potash; ammonium sulfate (a) after harvest, and (b) in the spring; and cottonseed meal in winter, which is the usual time for applying cottonseed meal fertilizer. All treatments were given to duplicate plots, randomized in two blocks. All plots received 1½ to 4 pounds of superphosphate per tree each year, and 1½ to 3 pounds of muriate of potash per tree annually, except the two plots in the no-potash treatment. The first application of the fertilizer treatments was made in the summer of 1938, as the "after-harvest" application.

The original rate of application in all treatments was 1 pound of nitrate of soda annually to each tree, or the equivalent in nitrogen from other carriers. Each half of a buffer tree received a corresponding half application. As the trees grew larger, the rate of application was increased to 2 pounds per tree in 1941 and 1942. This proved to be too great for the general vigor of the experimental trees, and the rate was reduced to 1 pound again in 1943, 1944, and 1945.

The land had never been in orchard, and for many years had been used for general farm crops. In the summer of 1937 the trees were intercropped with cotton. The following summer cowpeas were planted and cut for hay. An Austrian pea winter cover crop was grown the winter of 1938–1939, and turned under. After that clean cultivation was practiced. Weeds and grass were never allowed to grow more than a few inches high, and then only during harvest when cultivation was stopped.

Actual yield records were obtained on the basis of 16-quart picking buckets. Contents of partly filled buckets were estimated. The fruit was picked by a commercial picking crew, which swept through the experimental tree rows while harvesting the entire orchard. On an average nine separate pickings were made to harvest the crop. Trunk circumference measurements were made each winter. Ten representative terminal shoots were measured on each tree each season for terminal growth measurements. Total nitrogen was determined on 100-leaf samples.[1]

## Results

In Table I are summarized the effects of the various treatments on yield and maturity of fruit, growth of tree, and nitrogen content of leaves at harvest time. These data cover the entire course of the experiment, concluded after 7 years due to loss of trees principally from the virus disease, phony peach. Only the averages are presented because the response to treatment from year to year showed little variation and there was no crop failure in any year. For the first few years of the experiment, production in the check plots was on a par with the nitrogen fertilized plots. It was not until the fifth year of treatment, or 1943, that the effects of lack of nitrogen became pronounced in reducing yield. Even then the yield of the check plots was fairly good. The average yield per tree for the 6-year period, 1940 to 1945, was 2.89 bushels for the check plots, surpassed significantly only by the plots receiving the spring application of nitrate of soda and ammonium sulfate. Cottonseed meal and the after-harvest and fall applications of nitrate of soda did not significantly increase the yield of fruit.

Although yield of fruit was little affected by treatment, maturity of fruit was markedly delayed by every nitrogen treatment. This is shown in the third column of Table I, which gives percentage of fruit harvested early. Actually this represents the percentage of the crop ripening during the first 4 to 6 days of the harvesting period. The check plots matured the greatest percentage, 43 per cent, of its crop

[1]Grateful acknowledgment is made to L. O. Regeimbal for making these analyses.

in this period, significantly more than any other treatment. Among the nitrogen treatments nitrate of soda after-harvest and cottonseed meal caused the least delay in maturity, averaging 34 and 35 per cent, respectively. The spring application of nitrate of soda and of ammonium sulfate caused the greatest delay, with only 15 and 14 per cent, respectively, of the crop harvested in early pickings. Lack of potash did not significantly affect the yield or maturity of the fruit, when the no-potash treatment is compared with the other nitrate of soda spring plots receiving potash fertilizers.

Differences in trunk circumference in 1945, after 7 years of treatment, were small (Table I). Trees receiving spring applications of nitrate of soda or of ammonium sulfate were significantly larger than check trees and those receiving cottonseed meal.

Terminal growth measurements (Table I) show that all treatments increased terminal growth in comparison with check trees, and only in the case of cottonseed meal was the increase not significant. Nitrate of soda applied in the spring produced the greatest growth, significantly more than cottonseed meal or the after-harvest application of nitrate of soda or of ammonium sulfate. It is noteworthy that the check trees were able to maintain an average growth of 5.42 inches over the 5-year period without having received any nitrogen fertilizer during this time or the preceding 2-year period.

The nitrogen content of the leaves at harvest time for the 4-year period 1940 to 1943 (Table I) shows interesting differences due to both the time of application and the nitrogen carrier. Leaves on check plots were lowest in nitrogen. Cottonseed meal and after-harvest inorganic fertilizer treatments were slightly higher, though not significantly. Spring applications of nitrate of soda and of ammonium sulfate resulted in leaves with the highest nitrogen content at harvest time.

## Discussion

Viewing all of the data collectively, some close correlations are apparent in Table I. As the treatments increased the nitrogen content of leaves, the terminal growth, trunk circumference, and yield of fruit

TABLE I—Tree Response from Applications of Equivalent Amounts of Nitrogen to Elberta Peach Trees in Different Carriers and at Different Times of Year (Superphosphate Was Applied in All Treatments, and Potash in All But the Last)

| Treatment | Fruit Yield Per Tree 1940–45 (Bu) | Per Cent Crop Harvested Early 1940–45 | Trunk Circumference 1945 (Cm) | Terminal Growth 1941–45 (Ins) | Leaf Nitrogen at Harvest 1940–43 (Per Cent Dry Weight) |
|---|---|---|---|---|---|
| Check—no nitrogen | 2.89 | 43 | 42.5 | 5.42 | 2.37 |
| Nitrate of soda (harvest) | 3.11 | 34 | 45.3 | 7.81 | 2.61 |
| Nitrate of soda (fall) | 2.99 | 27 | 44.6 | 8.84 | 2.77 |
| Nitrate of soda (spring) | 3.25 | 15 | 47.8 | 9.71 | 2.87 |
| Nitrate of soda (bloom) | 3.32 | 22 | 45.4 | 9.39 | — |
| Ammonium sulfate (harvest) | 3.05 | 27 | 45.4 | 7.91 | 2.71 |
| Ammonium sulfate (spring) | 3.62 | 14 | 47.0 | 8.38 | 2.88 |
| Cottonseed meal (winter) | 2.81 | 35 | 42.0 | 6.49 | 2.64 |
| Nitrate of soda (spring—no potash) | 3.12 | 20 | 46.8 | 8.26 | — |
| L. S. D. at .05 level | 0.34 | 7 | 3.9 | 1.30 | 0.12 |

were increased. Maturity of fruit was delayed. The extent of these responses was a measure of the efficacy of the nitrogen carrier or of the time of application of the fertilizer. Because the amount of nitrogen applied to these trees was necessarily small, many of the responses were small also, but nevertheless they have significant meaning.

In considering the effect of time of application of nitrate of soda, it is obvious that spring applications were more effective than fall or after-harvest applications in increasing yield, trunk circumference, and terminal growth, as well as nitrogen content of leaves. They also delayed maturity the most. The after-harvest applications were slightly less effective than fall applications in these respects. The nitrogen content of the leaves in the after-harvest treatments approached that of the checks at the next harvest time, which is desirable from the standpoint of fruit color and early maturity. Also the after-harvest applications increased tree growth appreciably without seriously retarding maturity of the fruit. Applying nitrate of soda 2 weeks after bloom had no significant effect, as compared with applying it 2 weeks before bloom, on yield, ripening, trunk circumference or terminal growth.

Spring applications of ammonium sulfate also were more effective than the after-harvest applications in each response. The use of cottonseed meal fertilizer had only a slight effect, even though an equivalent amount of nitrogen was applied. It did delay maturity slightly, but did not influence the yield or growth of the trees significantly. Failure to apply potash fertilizer, as indicated by the results in the plots receiving nitrate of soda but no potash, did not significantly affect yield or maturity of fruit, or trunk circumference, although terminal growth was not so long as on other spring-fertilized plots.

In view of the slight effect these various fertilizer treatments had on yield and growth, it is surprising to note how greatly maturity was delayed. The amounts of nitrogen applied in this experiment were purposely kept low, so that the vigor of the trees would not be raised above a commercially desirable level. It was felt in 1942 that the 2-pound per tree applications were affecting the color of the fruit and delaying maturity too markedly, and the 1-pound rate of application was resumed. To have continued the 2-pound rate undoubtedly would have increased the differential response to the treatments, but to an undesirable extent.

Estimates of color on fruit were made each year just before harvest. These showed the fruit on the check trees to have the most color, and fruit from plots receiving spring applications of nitrate of soda or of ammonium sulfate the least. Other treatments ranged in between these extremes, much in accordance with relative time of maturity. The difference in color between plots was not so great as to cause serious objection to the use of nitrogen fertilizer in the amounts applied in these experiments except in 1942. Usually less color on an individual fruit meant only that its picking would be delayed another day or so. Nevertheless, the fruit on the check plots was the most attractive, and undoubtedly this feature by itself would have commanded a slightly higher price than that for fruit from the other plots.

## Summary

Spring applications of inorganic fertilizers were more effective in increasing yield and growth of Elberta peach trees than fall or after-harvest applications, but also delayed maturity of the fruit the most. After-harvest applications stimulated growth of tree with a minimum effect in retarding maturity of fruit. Cottonseed meal was relatively ineffective as a source of nitrogen under the conditions of this test.


## Literature Cited


1. Cowart, F. F., and Savage, E. F. The effect of nitrogen fertilization on yield and growth of Elberta peach trees. *Ga. Agr. Exp. Sta. Bul.* 253. 1947.
2. Weinberger, J. H., and Cullinan, F. P. Nitrogen intake and growth response in peach trees following fall and spring fertilizer applications. *Proc. Amer. Soc. Hort. Sci.* 32: 65–69. 1935.
3. Williams, C. F. Fall fertilization of peach trees in the Sandhills. *N. C. Agr. Exp. Sta. Bul.* 321. 1939.

# Irrigation of Citrus Orchards With Waters of Different Chemical Characteristics — A Progress Report[1]

By M. R. HUBERTY, *University of California, Los Angeles, Calif.*
and HAROLD E. PEARSON, *Metropolitan Water District, La Verne, Calif.*

To augment the natural water supply of the south coastal area of Southern California embracing parts of Los Angeles, Orange, Riverside, San Bernardino, and San Diego counties, waters from outside drainage basins have been imported. The latest of these developments brings water from the Colorado river through the aqueduct of the Metropolitan Water District of Southern California, Fig. 1. The vital need of water in this highly developed agricultural and industrial area supporting about half the population of California is apparent when one considers that stream run-off in this semi-arid section is less than 1 per cent of the total run-off for the state. Colorado river water to supplement local supplies was made available to the member cities of the District upon completion of the aqueduct system in the summer of 1941.

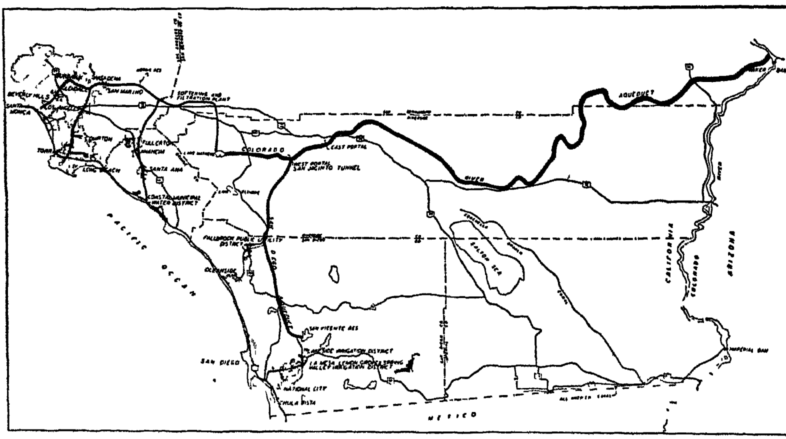


FIG. 1. Colorado river aqueduct.

Colorado river water is classed as a moderately high saline water, with a hardness of about 350 parts per million, expressed as $CaCO_3$. To make the water more suitable for domestic and industrial purposes, a water treatment plant was built near La Verne, California. A dual water softening process is employed, combining lime and zeolite treat-

[1]The authors wish to acknowledge the co-operation of members of the Metropolitan Water District staff assisting with this project: Julian Hinds, General Manager and Chief Engineer; R. B. Diemer, Chief Operation and Maintenance Engineer, who manages the groves; the late Geo. LeBaron, manager of the groves until 1946, and W. W. Aultman, Water Purification Engineer, in charge of the water softening and filtration plant.

ments (6). Prior to June, 1945 the hardness was reduced to about 100, but recently the hardness of the treated water has been about 125 ppm. Much concern has existed among farmers (3) and others over the effect these waters might have on the soil and subtropical fruit crops of the south coastal basin. This feeling is especially true regarding the use of treated, high sodium ratio water (5). Although Colorado river water has been used for irrigation for more than 60 years in the Palo Verde Valley of California, there is still some doubt concerning the use of the water for irrigation.

In order to answer some of these questions, a cooperative study of the effects of waters of different characteristics upon the soil and trees was undertaken by a division of the Agricultural Experiment Station, University of California, and the Metropolitan Water District.

Two orchards (Steve and Lamont) totalling 13.5 acres were selected from a total of 65 acres of citrus owned and operated by the District at the water treatment plant. In addition, the District established a water system which provides the following waters to segregated plots within the orchard, (a) natural Colorado river water, (b) filtered and softened Colorado river water, and (c) water of low salinity obtained from the local ground water basin. Characteristics of the waters used are represented in Table I. The orange groves contain rows of Washington Navel and Valencia orange trees and lemon trees. Fig. 2 is a map of the orchard showing the layout of the experiment.

The soil on which the orchards are planted belongs to the Ramona series (2), an alluvial fan soil with a moderately developed profile. This soil has been derived from igneous rock, high in quartz. It is brown in color and generally neutral in reaction. The approximate

TABLE I—ANALYSIS OF NATURAL COLORADO RIVER WATER, TREATED COLORADO RIVER WATER, AND LOCAL WELL WATER

| Date | pH | Milliequivalents per liter | | | | | | | | Per Cent Sodium* | Specific Electrical Conductance at 25 Degrees C $EC \times 10^6$ | Total Hardness as Ppm $CaCO_3$ | Total Solids Ppm | Boron Ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na | $CO_3$ | $HCO_3$ | $SO_4$ | Cl | $NO_3$ | | | | | |
| *Colorado River—Natural* | | | | | | | | | | | | | | |
| 1942–43 | 8.2 | 4.89 | 2.84 | 5.48 | 0 | 2.33 | 7.99 | 2.87 | 0.01 | 41 | 1,280 | 387 | 821 | 0.1 |
| 1943–44 | 8.1 | 4.79 | 2.71 | 5.39 | 0 | 2.35 | 7.74 | 2.79 | 0.01 | 42 | 1,260 | 375 | 803 | 0.2 |
| 1945 | 8.2 | 4.59 | 2.67 | 5.31 | 0 | 2.28 | 7.60 | 2.70 | Tr | 43 | 1,230 | 363 | 783 | 0.1 |
| 1946 | 8.2 | 4.44 | 2.63 | 5.18 | 0 | 2.35 | 7.18 | 2.59 | Tr | 42 | 1,180 | 353 | 757 | 0.1 |
| 1947 | 8.3 | 4.24 | 2.63 | 5.05 | 0 | 2.38 | 6.93 | 2.57 | Tr | 42 | 1,160 | 344 | 737 | 0.1 |
| *Colorado River—Treated Water* | | | | | | | | | | | | | | |
| 1942–43 | 8.7 | 1.20 | 0.82 | 11.00 | 0.26 | 1.72 | 7.99 | 3.05 | 0.01 | 84 | 1,370 | 101 | 850 | 0.1 |
| 1943–44 | 8.3 | 1.25 | 0.74 | 11.09 | 0.03 | 2.35 | 7.74 | 2.96 | 0.01 | 85 | 1,380 | 100 | 849 | 0.2 |
| 1945 | 8.6 | 1.25 | 0.86 | 9.92 | 0.13 | 1.80 | 7.60 | 2.88 | Tr | 83 | 1,300 | 106 | 796 | 0.1 |
| 1946 | 8.9 | 1.45 | 1.07 | 8.92 | 0.27 | 1.18 | 7.18 | 2.79 | Tr | 78 | 1,210 | 126 | 744 | 0.1 |
| 1947 | 9.1 | 1.45 | 1.15 | 8.48 | 0.43 | 0.93 | 6.93 | 2.76 | Tr | 77 | 1,170 | 130 | 724 | 0.1 |
| *Local Well* | | | | | | | | | | | | | | |
| Sep 2, 1942 | 7.6 | 2.54 | 1.32 | 1.39 | 0 | 3.07 | 0.83 | 0.65 | 0.69 | 26 | 510 | 193 | 330 | — |
| Jun 6, 1947 | 7.3 | 2.99 | 1.73 | 1.48 | 0 | 3.17 | 1.16 | 0.79 | 1.08 | 24 | 640 | 236 | 398 | — |

*Sodium as per cent of total cations as defined by Eaton (1).

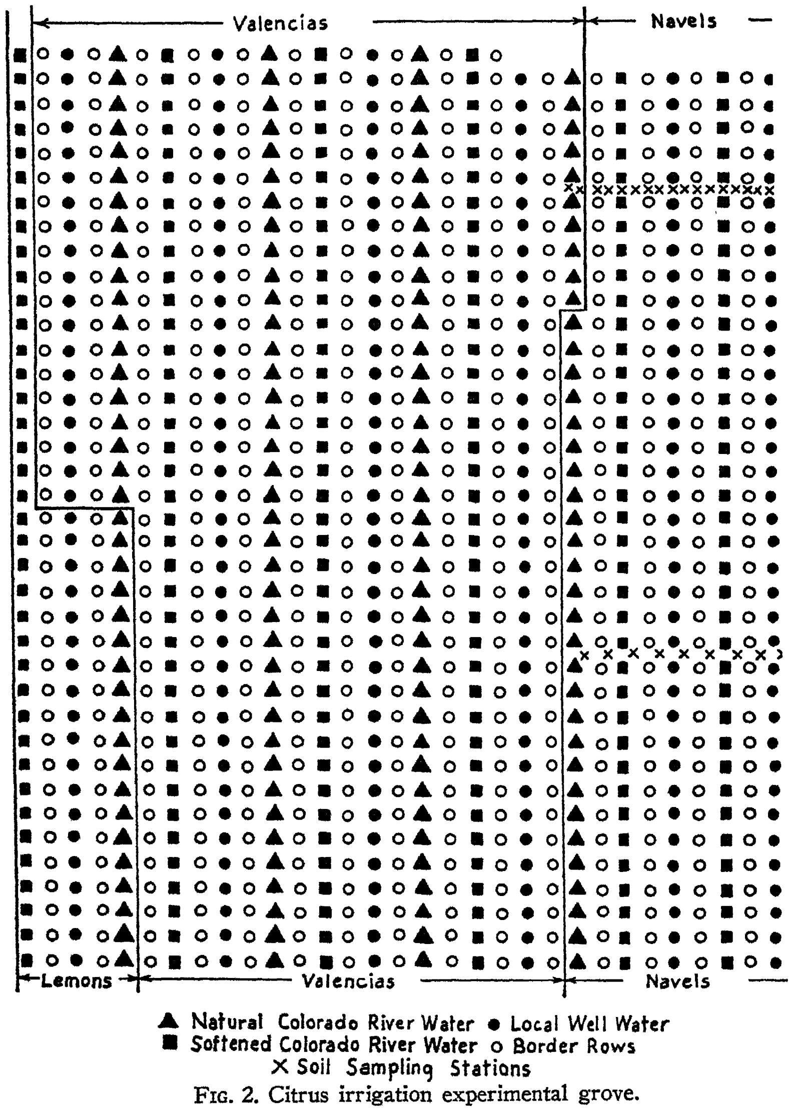



FIG. 2. Citrus irrigation experimental grove.

wilting percentages as measured by moisture retention capacities 15 atmospheres pressure (7) varied from 5.5 to 12.1 per cent, t higher values normally being for the subsoil.

## Cultural Practices

Some cultural practices may exert a marked influence on tree a soil conditions. Consequently, a detailed record of cultural operatic has been kept throughout the experiment, Table II.

TABLE II—RAINFALL AND CULTURAL PRACTICES

| Year | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 |
|---|---|---|---|---|---|---|
| Rainfall* | 11.26 | 13.78 | 18.55 | 15.33 | 13.11 | 12.81 |
| Irrigations | | | | | | |
| Number | 6 | 6 | 5 | 6 | 5 | 7 |
| Date of first | May 26 | Jun 5 | May 29 | May 28 | May 27 | Mar 31 |
| Date of last | Nov 20 | Nov 22 | Oct 16 | Dec 10 | Oct 21 | Oct 29 |
| Cultivation, number | - | 3 | 2 | 5 | 3 | 5 |
| Fertilizer | | | | | | |
| Inorganic, N, pounds/tree | 2 A | 1.7 B | 2 A | 2 C | 3 D | 3 E |
| Organic (manure) cu ft per tree | 10 | 0 | 15 S | 15 S | 10 | 8 |
| Zinc spray | Water | No | No | No | No | ZnO in oil |
| Pest Control | | | | | | |
| Aphids, nicotine dust | May | Apr | May | Apr | — | — |
| Rotanone oil spray | — | — | — | — | May F | Mar |
| Red spider, dust | — | Jan | — | Sep | Jul | Jun |
| Torthrix and thrip, dust | — | Jun | Jul | Aug | Jul | Jun |
| Red scale, oil spray | Sep | Oct | Dec | Oct | Sep | Nov |
| Brown Rot Bordeaux control | Dec | — | — | Dec | Nov | Dec |

*Rainfall reported seasonally, for example July 1, 1941 to June 30, 1942.
A—Ammonium sulfate
B—Sodium nitrate
C—1 pound from 16-20 ammonium phosphate and 1 pound, ammonium sulfate
D—2 pounds from ammonium nitrate and 1 pound from ammonium sulfate
E—Ammonium nitrate
S—Loose oat straw with a little horse manure
F—Valencias only

The time of the first irrigation depends largely on the distribution and amount of winter rainfall. The beginning of the irrigation season was determined by observing residual moisture. Subsequent irrigations were set at 5-week intervals until fall rains or cooler weather reduced the rate of moisture loss.

Tillage has been restricted, insofar as possible, to the control of volunteer or sown covercrop and weed growth, but occasionally leveling of the furrows was required to permit pest control operations. In certain parts of the grove, water infiltration rates in the middle furrows were low because cultivation had compacted the soil. In the four-furrow system the soil under the middle furrows was compacted by the wheels of tractors and fruit trucks. In 1946, a three-furrow system of irrigation was substituted for the four-furrow system. This has resulted in better water penetration, the present furrow absorbing about two-thirds as much water as the former two furrows. The net amount of water available to the plant under the two systems is probably about the same as there is less water lost by evaporation from the soil under the present practice.

During the war years, it was impossible to follow a consistent fertilizer program. Chemical nitrogen sources were restricted, and manure was hard to obtain because of labor shortages. In 1943, sodium nitrate was applied to the soil even though the experiment was planned to compare a high sodium versus low sodium waters. Since moisture penetration averaged only 20 to 24 inches after a 36-hour irrigation and since crowding of the trees reduced the growth of cover-crops which would supply a green manure, it seemed desirable to attempt to improve soil structure by adding liberal amounts of organic materials. In the case of other District groves using natural

Colorado river water exclusively, infiltration rates have improved sufficiently to reduce the irrigation time from 36 to 24 hours. As shown later, the application of organic material may have reduced somewhat the tendency of the high-sodium water to lower infiltration rates.

At the beginning of the experiment in 1942, the grove was treated with a zinc-water spray to correct for a slight mottle-leaf condition. (The bordeaux spray also contains zinc, but it is applied at a time when little of the zinc would be absorbed.) The pest control program was designed to give maximum protection to the trees and fruit in order to obtain high yields. Crowding of the trees because of overhanging branches finally became severe and during the early spring and summer of 1947, overhanging branches were pruned. This may lower yields of both Navels and Valencias in 1948, particularly in the Lamont Grove where the crowding was more severe.

## Results

Fruit yields, expressed in field boxes and as a ratio, are given in Table III for both the Navel and Valencia varieties. Differential irrigation treatment was initiated after the harvesting of the 1941–42 crop. Yields from the plots receiving the local water are used as base index (=100) for each year. If any influence on yields has been exerted by the Colorado river waters, it would be indicated by a change in the index.

The number of Navel orange trees receiving natural Colorado river water is relatively low, and the variability in annual tree yields

TABLE III—Average Seasonal Yields of Fruit by Variety and Irrigation Treatment

| Yield | No. Trees | Year | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1941–42 | 42–43 | 43–44 | 44–45 | 45–46 | 46–47 | 47–48 |
| *Navels* | | | | | | | | |
| Boxes* | | | | | | | | |
| 1 | 63 | 6 59 | 4.36 | 5.44 | 5.15 | 5.29 | 6.42 | 5.26 |
| 2 | 26 | 7.63 | 4.77 | 5.09 | 4.02 | 5.15 | 5.82 | 4.89 |
| 3 | 67 | 6.33 | 4.46 | 5.33 | 4.57 | 4.97 | 5.55 | 4.49 |
| Index† | | | | | | | | |
| 1 | 63 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 26 | 116 | 109 | 94 | 78 | 97 | 91 | 93 |
| 3 | 67 | 96 | 102 | 98 | 89 | 94 | 86 | 85 |
| *Valencias* | | | | | | | | |
| Boxes* | | | | | | | | |
| 1 | 116 | 4.71 | 3.67 | 3.62 | 5.11 | 4.24 | 4.37 | 3.94 |
| 2 | 89 | 4.84 | 3.91 | 3.86 | 4.48 | 4.36 | 4.40 | 3.97 |
| 3 | 102 | 4.91 | 3.83 | 3.80 | 4.64 | 4.08 | 4.26 | 3.82 |
| Index† | | | | | | | | |
| 1 | 116 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 89 | 103 | 106 | 107 | 88 | 103 | 101 | 101 |
| 3 | 102 | 104 | 104 | 105 | 91 | 97 | 98 | 97 |

*Average tree yield in field boxes.
†Average annual yield expressed as a per cent of the yield of treatment 1.
1. Plots receiving water from local wells.
2. Plots receiving natural Colorado river water.
3. Plots receiving treated Colorado river water.

is high. For statistical significance at the 1 per cent level an 0.8 box difference between treatments 1 and 2 is needed; whereas, only 0.6 box difference is required between treatments 1 and 3 with the larger number of trees. A slight trend to lower yields seems to appear with the Navel oranges irrigated with the Colorado river waters, but for the reasons mentioned, experimental error may account for the differences for the natural Colorado river water. No significant differences between treatments exists for the Valencia yields.

Changes in composition and in degree of soluble salt content of the soil in the various plots are shown in Table IV. Electrical conduc-

TABLE IV—RELATIVE CHANGES IN SOLUBLE SALT CONTENT OF SOIL AS INDICATED BY INDEXES OF CONDUCTIVITY (INDEX 100 FOR 1942 VALUES) AND PER CENT SODIUM IN WATER EXTRACTS

| Water | Depth (Ft) | Average Electrical Conductivity* at 25 Degrees C EC×10⁶ (1942) | Electrical Conductivity (Index) | | | | | | Per Cent Sodium in $H_2O$ Extract, (1947) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1942 | Fall 1943 | Spring 1944 | Spring 1945 | Spring 1946 | Spring 1947 | |
| Natural Colorado River | 1 | 583 | 100 | 82 | 121 | 118 | 99 | 76 | 48 |
| | 2 | 422 | 100 | 146 | 187 | 268 | 202 | 149 | 54 |
| | 3 | 375 | 100 | 172 | 164 | 207 | 175 | 207 | 56 |
| | 4 | 326 | 100 | 193 | 153 | 213 | 166 | 259 | 53 |
| | | | | 148 | 156 | 202 | 153 | 173 | |
| Treated Colorado River | 1 | 518 | 100 | 149 | 133 | 105 | 107 | 101 | 66 |
| | 2 | 460 | 100 | 143 | 166 | 129 | 145 | 203 | 71 |
| | 3 | 392 | 100 | 102 | 149 | 155 | 144 | 255 | 58 |
| | 4 | 403 | 100 | 106 | 124 | 152 | 120 | 203 | 56 |
| | | | | 125 | 143 | 135 | 129 | 190 | |
| Local | 1 | 475 | 100 | 77 | 108 | 67 | 76 | 83 | 31 |
| | 2 | 426 | 100 | 85 | 68 | 60 | 81 | 111 | 46 |
| | 3 | 337 | 100 | 89 | 98 | 72 | 88 | 136 | 58 |
| | 4 | 257 | 100 | 91 | 136 | 85 | 92 | 143 | 65 |
| | | | | 86 | 103 | 71 | 84 | 118 | |

*Two parts water to 1 part soil by weight.

tivity measurements were made on water extracts (2 water to 1 soil) of soil samples taken from the various plots, values obtained for the 1942 year being given an index value of 100. Increase in soluble salts is indicated by values above 100, decreases by index numbers less than 100. The data indicate that although not yet high, a considerable increase of salines has occurred below the 1-foot level on those plots receiving the Colorado river waters. The salinity of the soil solution is from four to eight times as concentrated as the irrigation water. Lateral movement of the salines into the non-irrigated areas between furrows has not been marked. Analyses of water extracts of soils collected during the spring of 1947 show a difference in sodium percentage, the plots receiving treated water having the highest sodium percentage in the upper 2 feet of soil and approximately the same percentage as the other treatments in the third and fourth feet.

Determinations of pH made on water extracts (2 water to 1 soil) prior to differential treatment, 1942, and again in 1947, show no significant change, the soil reaction being in the range classed by soil scientists as neutral.

TABLE V—COMPOSITION OF SATURATION EXTRACT AND NATURE OF EXCHANGEABLE BASES IN SOILS RECEIVING WATER OF DIFFERENT CHEMICAL CHARACTERISTICS (SAMPLES TAKEN SEPTEMBER 1947)

| Location | Depth (Ft) | Per Cent Moisture at Saturation S P | Electrical Conductivity at 25 Degrees C $EC \times 10^6$ | Saturation Extract ME/100 Grams of Dry Soil | | | | | Per Cent Na | Exchangeable Bases ME/100 Grams of Dry Soil | | | | | Per Cent Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ca | Mg | K | Na | Total | | Ca | Mg | K | Na | Total | |
| *Natural Colorado River Water* | | | | | | | | | | | | | | | |
| Steve 23.... | 0–1 | 31.2 | 2,068 | 0.34 | 0.13 | 0.04 | 0.22 | 0.73 | 30 | 7.45 | 1.72 | 0.93 | 0.52 | 10.62 | 4.9 |
| Lamont 23.. | 0–1 | 38.3 | 1,800 | 0.35 | 0.12 | 0.03 | 0.30 | 0.80 | 38 | 15 80† | 4.01 | 0.97 | 0.75 | 21.53† | 3.5 |
| *Treated Colorado River Water* | | | | | | | | | | | | | | | |
| Steve 25.... | 0–1 | 29.6 | 2,077 | 0.24 | 0 07 | 0.01 | 0.36 | 0.68 | 53 | 7.54 | 1.23 | 0.82 | 0 68 | 10.27 | 6.4 |
| Lamont 25.. | 0–1 | 38.3 | 2,681 | 0.43 | 0.16 | 0.02 | 0.59 | 1 20 | 49 | 16.49† | 3.94 | 0.93 | 1.44 | 22.80† | 6.3 |
| *A**....... | 0–0.1 | 36.2 | 4,649 | 0.73 | 0.39 | 0.09 | 1.02 | 2 23 | 46 | 8.00 | 2.35 | 0.28 | 0.83 | 11.46 | 7.2 |
| *B*........ | 0–0.1 | 36.5 | 4,607 | 0.60 | 0.28 | 0.08 | 1.08 | 2.04 | 53 | 6.98 | 2.24 | 0.54 | 0 96 | 10.72 | 8 9 |
| *C* ...... | 0–0.5 | 35.0 | 1,408 | 0.14 | 0.06 | 0.08 | 0.32 | 0.60 | 53 | 7.33 | 2.04 | 0.40 | 0 67 | 10.44 | 6 4 |
| *D*........ | 0–0.5 | 35.0 | 1,448 | 0.12 | 0.04 | 0.06 | 0.33 | 0.55 | 60 | 6.48 | 2.02 | 0.49 | 0.69 | 9.68 | 7.1 |
| *Local Water* | | | | | | | | | | | | | | | |
| Steve 30.... | 0–1 | 32.3 | 2,193 | 0.48 | 0.13 | 0.03 | 0.18 | 0.82 | 22 | 13.27† | 2.36 | 0.87 | 0.53 | 17.03† | 3 1 |
| Lamont 27.. | 0–1 | 39.0 | 1,102 | 0.25 | 0.10 | 0.02 | 0.13 | 0.50 | 26 | 18.10† | 4.36 | 0.79 | 0.51 | 23.76† | 2.1 |

*Soil surface from Lamont Row 1: *A* From furrow bottom, *B* from furrow side, *C* from furrow bottom, *D* from furrow side.
The soil for samples A, B, C, and D had remained undisturbed throughout entire irrigation season.

†Method of extracting and determining exchangeable bases were essentially those reported by Schollenberger and Simon (8), except that magnesium was determined by the 8-OH quinolate method. Higher values for exchangeable calcium and total exchange capacity in marked samples while due, in part, to solubility of calcium carbonate during ammonium acetate leaching, they are principally due to the variable clay content of the soil at different locations: Steve 23 and 25 contained about 14 per cent clay, Steve 30–18 per cent, and Lamont 23, 25, and 27–23 to 25 per cent.

The data of Table V represent analyses of water extracts from saturated soil samples and the nature of the exchangeable bases. Both for the water extracts and for the degree of sodium saturation, the plots irrigated with treated water show the highest sodium percentages. This is especially true of the surface soil from the furrow bottoms and sides. The degree of sodium saturation is especially significant in relation to water penetration. Further observations on the rate and extent of changes in the absorbed sodium content of the soil colloid will be made.

While the table just discussed represents chemical changes in the soil, Table VI reports results indicating changes in the physical conditions associated with these different chemical characteristics. No difference in rate of water entry into the soil from similar furrows receiving the three waters was apparent at the beginning of the irrigation. However, differences became noticeable the longer the water was allowed to run with the treated water showing a more marked lowering of infiltration rates. It is probable that the application of organic matter may have prevented greater differences in infiltration rates in the case of the high sodium water (4).

TABLE VI—AVERAGE INFILTRATION RATES FOR THE VARIOUS WATERS, EXPRESSED AS GALLONS/MIN/430 FEET OF FURROW

| Date | Elapsed Time (Hours) | Natural Colorado River Water | | Treated Colorado River Water | | Local Water | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 1 | 2 | 1 | 2 |
| Sep 6, 1943 ....... | 5 | 3.79 | 2.42 | 4.31 | 2.21 | 5.14 | 2.30 |
| Sep 6, 1943....... | 31 | 2.16 | 1.22 | 1.89 | 0.66 | 2.98 | 0.99 |
| May 29, 1944...... | 7–8 | 5.77 | 4.09 | 6.83 | 3.71 | 5.96 | 4.42 |
| May 29, 1944...... | 30 | 5.34 | 2.26 | 3.68 | 1.51 | 3.69 | 1.89 |
| Jul 3, 1944........ | 30 | 4.33 | 1.20 | 3.62 | 0.81 | 4.31 | 0.79 |
| Sep 22, 1947....... | 6–7 | 5.15 | 3.94 | 4.86 | 4.14 | 4.11 | 3.67 |
| Sep 22, 1947...... | 30 | 2.58 | 1.57 | 1.68 | 1.27 | 2.18 | 1.56 |

1—Tree furrow.
2—Middle furrows.

The observation of tree vigor and yields will be continued to determine how the changed soil conditions may influence the productive capacity of the trees. In addition, the size of the plots will permit split treatments to measure the ameliorating effect of soil amendments which may be needed to replenish the calcium reserves in the soil irrigated with the high-sodium water.

## SUMMARY

The paper presents a cooperative progress report covering 6 years of study of the effect of waters of different chemical characteristics on mature orange orchards, as measured by tree and soil responses. The soil is a medium-textured, semi-mature secondary soil derived from igneous rock high in quartz. The B horizon is quite well developed, thereby restricting the ready movement of water through the soil profile.

While no apparent differences in tree vigor and only small changes in fruit yield have been produced by the use of natural Colorado river water or treated Colorado river water, measurable changes in the physical and chemical characteristics of the soil are beginning to appear. Some increase in soluble salt content of the soil has occurred, especially in the 2- to 4-feet depths. Some reduction in reserve calcium in the upper 2 feet of soil has occurred in the plots receiving treated water.

## Literature Cited

1. Eaton, F. M. Boron in soils and irrigation waters and its effect on plants. *U. S. D. A. Tech. Bul.* 448: 39. 1935.
2. Echman, E. C., and Zinn, C. J. Soil survey of the Pasadena area, Calif. *U. S. D. A. Bur. of Soils*: 1–56. 1917.
3. Gilman, H. S. Problems of the citrus grower with respect to quality of water. *Proc. Joint Meeting, Com. of the States and Colorado Drainage Basin Com. of the National Resources Com.*, pp. 113–21. June 5–6, 1939.
4. Huberty, M. R., and Pillsbury, A. F. Factors influencing infiltration rates into some California soils. *Amer. Geophys. Union Trans.* 1941: 686. 1941.
5. Magistad, O. C. The use of softened Colorado river water for home gardens. *Jour. A. W. W. A.* 33: 883. 1941.
6. Montgomery, James M., and Aultman, William W. Water softening and filtration plant of the Metropolitan Water District of Southern California. *Jour. A. W. W. A.* 32: 1. 1940.
7. Richards, L. A., and Weaver, L. R. Moisture retention by some irrigated soils as related to soil-moisture tension. *Jour. Agr. Res.* 69: 215–235. 1944.
8. Schollenberger, C. J., and Simon, R. H. Determination of exchange capacity and exchangeable bases in soil — ammonium acetate method. *Soil Sci.* 59: 13–24. 1945.

# Phosphate Fertilizer Trials With Oranges in Florida I. Effects on Yield, Growth, and Leaf and Soil Composition

By WALTER REUTHER, FRANK E. GARDNER, PAUL F. SMITH, and WALLACE R. ROY,[1] *U. S. Department of Agriculture, Orlando, Fla.*

THERE is little published evidence on the effect of phosphate fertilization on citrus production and fruit quality in Florida, although it has been common practice to use mixed fertilizers rich in phosphate almost since the beginning of the Florida industry. Forsee and Neller (12) have reported yield and growth responses of oranges to various phosphatic materials on the organic soils of the eastern Everglades, but there are no recent published data for the sandy mineral soils on which most of the Florida citrus plantings are made.

In other citrus growing regions of the United States, California workers (5, 19) concluded from extensive field trials and pot studies that most California citrus soils contain ample available phosphate; similar conclusions have been reached in Arizona (11) and Texas (13). In the South African citrus growing regions several workers have noted yield responses to phosphate fertilization with oranges on certain soils deficient in phosphate (1, 18). Fertilizer experiments with grapefruit in two locations in Jamaica reported by Innes (15) indicate a response to phosphate in one of the locations, but not in the other.

The purpose of this paper is to present a progress report on two long-term field experiments. Four levels of phosphate fertilization on oranges are compared in two locations. Both are on acid, well-drained, light sandy soils low in exchange capacity, which are typical of the major soil type used for citrus culture in Florida. This report is concerned with yield and growth data, soil changes, and leaf analysis. An accompanying paper (25) is devoted to the effect of phosphate fertilization on certain fruit qualities.

## EXPERIMENTAL METHODS

*Plan of Valencia Experiment:*—The first series of phosphate plots was established in 1942 in a block of Valencia oranges on rough lemon stock planted in 1923 near Dunedin in Pinellas County. This irrigated 10-acre grove on a hammock phase of Lakeland fine sand (formerly called Norfolk fine sand) was chosen for this purpose

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[1]Formerly Associate Biochemist, U. S. Department of Agriculture, now Chief Chemist, Vacuum Foods Corp., Plymouth, Fla.

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partly because it had received far less phosphate fertilization than most groves in Florida of comparable age. The grower's records revealed that during the first 11 years (1923 through 1933) after planting it received less than one-half as much $P_2O_5$ per acre as nitrogen. In 1934 colloidal phosphate at the rate of 1000 pounds per acre was applied to the soil. During the period from 1935 until 1942, most of the mixtures applied contained no phosphatic fertilizer materials, although small amounts of $P_2O_5$ were, of course, contained in the organic nitrogen sources used.

A system of 20 plots was established on about 4½ acres of the most uniform portion of the grove. Each plot consists of 16 trees, and is completely surrounded by buffer rows. Since the planting distance is 15 by 25 feet, the fertilized area for each plot plus one-half of the area occupied by the surrounding buffer trees is about 0.215 acres. Four treatments, arranged in random fashion, were established in each of five blocks. Statistical examination of the 1942 yield data obtained before differential treatments were started revealed that there was a significant difference in yield among the five blocks, but no significant variance in yield among the four groups of plots to which the several treatments had been assigned.

During the experimental period 1942 through 1948 all plots and buffer trees received uniform poundages (applied by machine) of mixed fertilizers containing nitrogen, potash, soluble magnesium, several minor elements, and dolomitic limestone filler. With the exception of the first year, no organic nitrogen was applied. Hence only the traces of $P_2O_5$ present in some of the inorganic materials, and minor quantities included by contamination from mixing machinery, were contained in these fertilizers. These sources probably contributed less than 0.01 pound of $P_2O_5$ per tree per year. The sources of nitrogen were sulfate of ammonia, ammonium nitrate, and nitrate of soda. Potash was derived from sulfate of potash-magnesia and muriate. Soluble magnesium was obtained from sulfate of potash-magnesia. Dolomitic limestone was the only filler used. The amounts of each of the elements applied each crop year are presented in Table I.

During the three crop years[2] 1942–43 through 1944–45, the 8–0–8 mixture was used three times a year as follows: 50 per cent of the total annual poundage was applied in November or December, 30 per cent in March or April, and 20 per cent in May or June. Beginning with the 1945–46 crop year, this program was changed so that about 70 per cent of the total annual supply of nitrogen was applied in the fall from ammonium nitrate, and no other fertilizer elements were applied at this time. The rest of the nitrogen and all of the annual dosage of the other major and minor elements were applied in two equal applications in spring and summer from a 5–0–18 mixture. Dolomitic limestone was applied to all plots at the rate of 1200 pounds per acre in March, 1946 and 900 pounds per acre in May, 1948. The method of timing nitrogen applications and the ratio of nitrogen to potash in this experiment both diverge from common practices (4).

[2]With the Valencia variety in Florida, the crop is set in the spring of the year, but harvested in the spring or early summer of the following year.

The differential phosphate treatments were applied separately by hand in three applications per year for the first three crop years and in only two applications during the last three crop years. Plots designated A received no phosphate at all. The B plots received approximately one, the C plots three, and the D plots eight units of $P_2O_5$ for each four units of nitrogen applied. This last ratio of phosphate to nitrogen approximates standard practice in the majority of citrus growing sections of Florida. The phosphate source used was 20 per cent superphosphate. This material contains approximately 50 per cent of gypsum. Compensating amounts of gypsum were added to the other treatments so that all received approximately the same dosage of this slightly soluble source of calcium. No effort was made to compensate for the calcium supplied by the several calcium phosphate salts in superphosphate. The amounts of $P_2O_5$ and gypsum applied in the various treatments are presented in Table I.

The trees appeared to be of normal vigor and density of foliage during the test period. An adequate pest control program was used throughout the experiment. Zinc and copper nutritional sprays were used in some years.

*Plan of Pineapple Experiment:*—The second phosphate fertilizer experiment was established in a block of young Pineapple oranges on rough lemon stock. This grove was planted in March 1943 on a recent-

TABLE I—SUMMARY OF FERTILIZER TREATMENTS TO VALENCIA PHOSPHATE PLOTS

| Fertilizer Element | Crop Year* (Pounds Per Tree Per Year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1941–42* | 1942–43 | 1943–44 | 1944–45 | 1945–46 | 1946–47 | 1947–48 |
| | | | *All Plots* | | | | |
| N | 1.23 | 1.52 | 1.60 | 1.60 | 1.80 | 2.25 | 1.92 |
| $K_2O$ | 0.96 | 1.52 | 1.60 | 1.60 | 1.80 | 2.25 | 2.25 |
| MgO† | N.R.‡ | 0.32 | 0.54 | 0.54 | 0.60 | 0.75 | 0.75 |
| MnO | N.R. | 0.12 | 0.14 | 0.20 | 0.20 | 0.25 | 0.25 |
| CuO | N.R. | 0.06 | 0.10 | 0.20 | 0.20 | 0.25 | 0.25 |
| ZnO | N.R. | 0.08 | 0.08 | 0.08 | 0.10 | 0.13 | 0.13 |
| $B_2O_3$ | N.R. | 0.008 | 0.011 | 0.018 | 0.020 | 0.023 | 0.023 |
| $Fe_2O_3$ | N.R. | 0.19 | 0.20 | 0.20 | 0.20 | 0.25 | 0.25 |
| Dolomite | N.R. | 1.0 | 5.3 | 4.3 | 13.6 | 0.9 | 8.7 |
| | | | *A Plots* | | | | |
| $P_2O_5$ | 0.0 | 0.05 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $CaSO_4$ | 1.29 | 6.48 | 9.60 | 9.60 | 9.60 | 11.2 | 11.2 |
| | | | *B Plots* | | | | |
| $P_2O_5$ | 0.07 | 0.38 | 0.48 | 0.48 | 0.48 | 0.56 | 0.56 |
| $CaSO_4$ | 1.13 | 5.67 | 8.40 | 8.40 | 8.40 | 10.2 | 10.2 |
| | | | *C Plots* | | | | |
| $P_2O_5$ | 0.19 | 1.02 | 1.44 | 1.44 | 1.44 | 1.68 | 1.68 |
| $CaSO_4$ | 0.80 | 4.05 | 6.00 | 6.00 | 6.00 | 7.00 | 7.00 |
| | | | *D Plots* | | | | |
| $P_2O_5$ | 0.48 | 2.64 | 3.84 | 3.84 | 3.84 | 4.46 | 4.46 |
| $CaSO_4$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

*Differential treatments were started May, 1942, but the crop year is considered to begin with the fall fertilizer application. With Valencias in Florida the fruit is usually on the tree 12 to 15 months from set (about March) to harvest.
†Water-soluble MgO.
‡N.R.—No record.

ly cleared tract of virgin Lakeland sand located near Tavares in Lake County. Twenty-four plots of 12 trees each were laid out with guard rows separating the plots. The planting distance is 20 by 30 feet. The random-block design used consists of six blocks of four plots each. The four fertilizer treatments in each block are essentially the same as those used in the Valencia experiment, and bear the same designations, but of course smaller quantities were used for these young trees. The differential phosphate treatments were begun in the spring of 1944, 1 year after the young trees were planted. During the first season after planting the young trees in all plots were fertilized with a total of about 5 pounds per tree of 8–0–8 fertilizer that contained about 0.4 per cent $P_2O_5$ in the castor pomace, so that each tree received an initial application of about 0.02 pounds of $P_2O_5$. After differential treatment began, all plots were fertilized three times per year with an 8–0–8 mixture containing 3 to 4 per cent of soluble MgO, 2 per cent MnO, 1 per cent CuO, 0.1 per cent $B_2O_3$, and 100 to 200 pounds of dolomite filler. Organic nitrogen carriers such as castor pomace or tobacco stems usually supplied from 8 to 15 per cent of the nitrogen in the mixture, and contributed a maximum of about 0.05 pounds of $P_2O_5$ per tree per year to all plots. Currently 5 to 6 pounds of this mixture per tree are applied by machine at each application. The trees in all plots have made good to excellent growth since planting, and appear vigorous and healthy. None of the plots has been seriously injured by frost to date.

*Analytical Methods:*—Leaves for analysis were scrubbed in a neutral detergent solution (sodium lauryl sulfate), rinsed repeatedly in distilled water, oven dried, weighed, and then ground to a fine powder. The major constituents were determined on ashed portions by the methods described in an accompanying paper (25). The trace elements and sodium were determined by spectrographic methods (9).

Soil samples were analyzed for exchangeable bases, water-soluble phosphorus, and acid-available phosphorus essentially by the methods of Peech, *et al* (23). Total phosphorus in the soil was determined in a suitable aliquot of an extract obtained by digesting 25 grams of soil for 1 hour with 30 ml of a mixture of equal parts of 6 N HCl and 9 N $HNO_3$.

## Experimental Results

*Yield:*—The effect of phosphate fertilization on yield of fruit in the Valencia experiment is summarized graphically in Fig. 1. It will be noted that there was no substantial difference in yield among the various treatments at the outset of the experiment (1942 harvest data) or during the first three years of differential treatment. The 1946 yield data (for the crop which was set in the spring of 1945, but harvested in May of 1946), when considered alone, indicate a highly significant increase in yield due to phosphate fertilization. However, the isolated 1947 data indicate a significant decrease in yield associated with phosphate fertilization. In 1948 this trend is again reversed, and the variation in yield due to treatment approaches high siginficance. The general increase in yield in 1948 appears to be due to

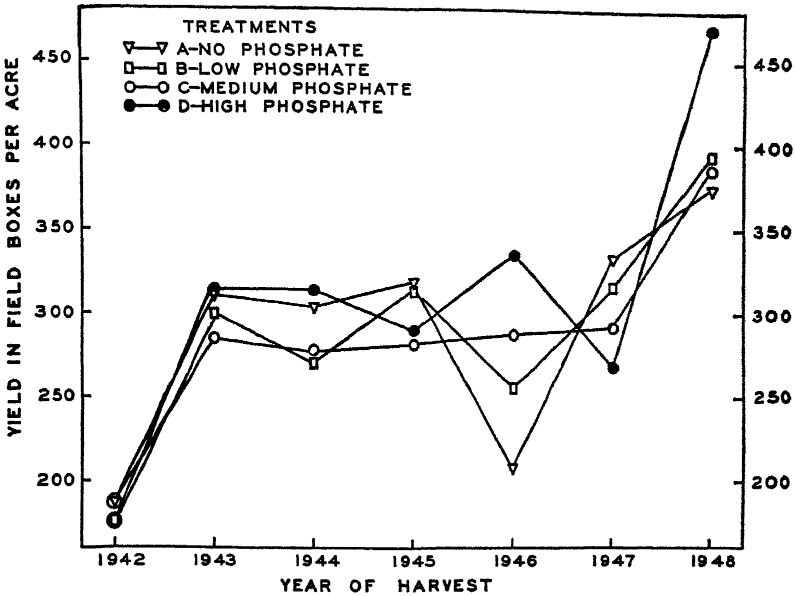


FIG. 1. A graphic presentation of the yield data in field boxes per acre from the Valencia experiment during the period from 1942 through 1948.

the increase in fertilization beginning in the fall of 1946 (see Table I). The grand annual yield means for the 6-year period of differential treatment are as follows:

| *Treatments* | *Grand Yield Means Per Year* *Pounds Per Tree* | *Boxes Per Acre* |
|---|---|---|
| A—No $P_2O_5$ | 251 | 307 |
| B—Low $P_2O_5$ | 253 | 309 |
| C—Medium $P_2O_5$ | 247 | 302 |
| D—High $P_2O_5$ | 272 | 332 |

The yield data from these plots during the six seasons of differential treatment were examined statistically by the analysis of variance method (26) in order to evaluate the effects of treatment, blocks, season, and the interaction of these factors. These calculations indicate that the variance among the grand treatment means presented above is not significant. On the other hand, the variance due to blocks (soil and other positional factors) and season (comprising both climatic and cultural factors) are highly significant. The interactions discussed below tend to minimize the importance of these "main effect" statistical relationships.

There was a highly significant interaction of season with treatment; that is, the effect of treatment was not the same in all seasons. Examination of the data in Fig. 1 show that beginning with the 1947 season, appreciable alternate bearing developed in certain of the treatments. The A and B plots have their light crop or "off year" in 1946,

and their "on year" in 1947, while the reverse was true for the D plots. The D plots are currently leading in yield because of the two "on" years and one "off" year. Some factor, possibly the severe drought of the spring and early summer of 1945, seems to have caused the sharp accentuation of the alternate bearing tendencies discernible in the 1943, 1944, and 1945 yield data. Whether the difference between the alternate bearing cycle of the A and B plots and that of the D plots is a real and significant effect of phosphate fertilization is not clear. The means of the yields of the five C plots show a remarkable absence of alternation, although there was decided alternate bearing among individual C plots during the 6-year period; this suggests the possibility of chance relationship. Moreover, when data for the mean yield by blocks for the 6 years are plotted in a manner similar to the groups of treatment plots presented in Fig. 1, a distinct biennial bearing trend is discernible in individual blocks of treatments. The fact that there was a statistically significant interaction of season with blocks also indicates that the relative yield of the several blocks was not the same in all seasons. Perhaps yield data in subsequent seasons will shed additional light on this question.

Yield data were obtained in 1947 and 1948 from the Pineapple experiment. The mean yields per tree were as follows:

| *Treatment* | *Yield (Pounds Per Tree) for 1947 Crop* | *1948 Crop* |
|---|---|---|
| A—No $P_2O_5$ | 35 | 91 |
| B—Low $P_2O_5$ | 39 | 83 |
| C—Medium $P_2O_5$ | 43 | 90 |
| D—High $P_2O_5$ | 40 | 94 |

The 1948 harvest records were obtained after 4 years of differential treatment on 5-year-old trees. It is apparent that there were no significant effects of treatment on yield in either year.

*Growth:*—Trunk circumference measurements were made on the test trees at the outset of the Valencia experiment in 1942, and almost annually thereafter. The data obtained indicate that the medium and heavy phosphate treatments were associated with depressed growth as measured by the percentage increase in cross-sectional area of trunks. Similar data obtained from the Pineapple plots indicate no significant effect of treatment during the 1944–1947 period. These data are summarized in Table II.

*Leaf Composition:*—Composite leaf samples were obtained from 1-year-old leaves on bearing terminals in April 1942 from each of the 20 Valencia plots. These were analyzed for all of the elements listed in Tables III and IV, except boron and sodium. These analyses indicated that initially there were no significant differences in leaf composition among the groups of plots to which the four fertilizer treatments were assigned. Leaf samples were not collected again from these plots until midsummer of 1946 and of 1947, when the method of collecting samples was changed. About August 1 of each year single leaves were harvested from four to six nonfruiting, spring-flush twigs distributed around each of the central eight trees in each plot, amount-

TABLE II—THE EFFECT OF PHOSPHATE FERTILIZATION ON THE INCREMENT IN CROSS-SECTIONAL AREA OF TRUNK OF ORANGE TREES

| Treatment | Valencia Plots | | | Pineapple Plots | | |
|---|---|---|---|---|---|---|
| | Mean X-Sec $Cm^2$ | | Per Cent Increase | Mean X-Sec $Cm^2$ | | Per Cent Increase |
| | 1942 | 1948 | | 1944 | 1947 | |
| A—No $P_2O_5$ | 298.6 | 382.5 | 28.2 | 8.4 | 52 8 | 526 |
| B—Low $P_2O_5$ | 279.4 | 354.3 | 36.9 | 8.4 | 49.7 | 492 |
| C—Medium $P_2O_5$ | 266.4 | 329.7 | 23.8 | 8.3 | 52.6 | 531 |
| D—High $P_2O_5$ | 287.4 | 355.9 | 23.9 | 7.9 | 49.3 | 515 |
| Effect of treatment | N.S. | * | * | N.S. | N.S. | N.S. |
| L.D. at .05 | — | 31.2 | 3.5 | — | — | — |

Statistical symbols:
N.S. = Not significant.
* = Significant (F value between .05 and .01 level).
L.D. = Least difference for significant between any two means.

TABLE III—SUMMARY OF ANALYSES OF FOLIAGE FROM THE VALENCIA EXPERIMENT (1946 AND 1947 SEASONS)

| Treatment and Statistical Indices | 'Mean Dry Weight Per Leaf (Mg) | Mean Percentage in Dry Matter | | | | |
|---|---|---|---|---|---|---|
| | | N | P | K | Ca | Mg |
| | | *1946 Season* | | | | |
| A—No $P_2O_5$ | 400 | 2.80 | 0.142 | 1.66 | 3.70 | 0.400 |
| B—Low $P_2O_5$ | 380 | 2.64 | 0.150 | 1.58 | 3.56 | 0.390 |
| C—Med. $P_2O_5$ | 398 | 2.70 | 0.150 | 1.68 | 3.76 | 0.350 |
| D—High $P_2O_5$ | 376 | 2.68 | 0.156 | 1.68 | 3.64 | 0.332 |
| Effect of treatment | N.S. | N.S. | ** | N.S. | N.S. | * |
| L.D. at .05 | — | — | 0.006 | — | — | 0.046 |
| L.D. at .01 | — | — | 0.009 | — | — | 0.064 |
| | | *1947 Season* | | | | |
| A—No $P_2O_5$ | 276 | 2.82 | 0.136 | 1.72 | 3.06 | 0.350 |
| B—Low $P_2O_5$ | 272 | 2.84 | 0.143 | 1.70 | 3.16 | 0.358 |
| C—Med. $P_2O_5$ | 274 | 2.86 | 0.145 | 1.70 | 3.22 | 0.344 |
| D—High $P_2O_5$ | 298 | 2.82 | 0.152 | 1.52 | 3.76 | 0.332 |
| Effect of treatment | N.S. | N.S. | ** | * | ** | N.S. |
| L.D. at .05 | — | — | 0.007 | 0.15 | 0.30 | — |
| L.D. at .01 | — | — | 0.010 | 0.21 | 0.42 | — |

Statistical symbols:
N.S. = Not significant.
* = Significant (F value between .05 and .01).
** = Highly significant (F value above .01 level).
L.D. = Least difference for significance between any two means.

TABLE IV—SUMMARY OF TRACE ELEMENT ANALYSIS OF FOLIAGE FROM THE VALENCIA EXPERIMENT (1947 SEASON)

| Treatments and Statistical Indices | Mean Parts Per Million in Dry Matter | | | | | |
|---|---|---|---|---|---|---|
| | Zn | Mn | Cu | B | Fe | Na |
| A—No $P_2O_5$ | 24.4 | 38.6 | 9.4 | 152 | 60.9 | 462 |
| B—Low $P_2O_5$ | 25.8 | 41.1 | 8.9 | 158 | 58.9 | 461 |
| C—Med. $P_2O_5$ | 36.0 | 46.0 | 8.4 | 143 | 59.2 | 491 |
| D—High $P_2O_5$ | 40.8 | 52.3 | 7.2 | 140 | 57.6 | 467 |
| Effect of treatment | ** | ** | ** | N.S. | N.S. | N.S. |
| L.D. at .05 | 3.3 | 5.0 | 1.1 | — | — | — |
| L.D. at .01 | 4.6 | 7.0 | 1.6 | — | — | — |

Statistical symbols:
N.S. = Not significant.
** = Highly significant (F value above .01 level).
L.D. = Least difference for significance between any two means.

ing to a total of 48 leaves per sample in 1946 and 32 leaves per sample in 1947. Spring-flush twigs supporting June flush shoots were avoided, as were twigs with damaged or abnormal leaves. These leaves were between 4 and 5 months old at the time of harvest. The summaries of the analyses of these foliage samples are presented in Tables III and IV.

In both the 1946 and the 1947 leaf samples the effect of phosphorus fertilization was reflected in the phosphorus content of the leaves. The amount of phosphorus in the foliage from the high phosphate plots was only 10 to 12 per cent greater than that in the no phosphate plots, but statistically this difference is highly significant. Contrary to evidence with many plants, phosphate fertilization did not depress significantly the nitrogen content of the foliage sampled in either year. There was no significant effect of treatment on spring-flush leaf size in either season, but the 1946 leaves were considerably heavier than the 1947 leaves. The latter were produced in a year when bloom was from four to six weeks later than normal.

In 1946 there was an indication of a depressing effect of heavy phosphate fertilization on the magnesium content of the foliage. A similar trend was apparent in the 1947 leaves, but was not of sufficient regularity to reach statistical significance. Recent observations (August, 1948) reveal that there is a slight amount of magnesium deficiency symptoms in the heavy phosphate plots, but none in any of the other treatments. These analyses and observations suggest that heavy phosphate fertilization may have induced slight magnesium stress, particularly in the heavy crop years of 1946 and 1948.

There was no effect of phosphate fertilization on either the potassium or the calcium content of the foliage in 1946. In 1947 phosphate fertilization increased the calcium content of the foliage slightly, but significantly, and as would be expected, there was a parallel decrease in potash content.

No data on the trace element concentrations are available for the 1946 season, but the data for the 1947 foliage samples presented in Table IV indicate that phosphate fertilization increased zinc and manganese in the foliage, but decreased copper. The magnitude of these effects of treatment are greater than those for the major elements. There appears to be no significant effect of treatment on the boron, iron, or sodium content of the foliage.

The data presented in Table V summarize the analyses of spring flush leaves 4 to 5 months old collected July 29, 1947, from the Pineapple plots. Each sample consisted of one leaf from each of 10 twigs

TABLE V—SUMMARY OF ANALYSES OF FOLIAGE FROM THE PINEAPPLE EXPERIMENT (1947 SEASON)

| Treatments | Mean Leaf Weight (Mg) | Mean Percentage in Dry Matter | | | | | Mean Parts Per Million in Dry Matter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Ca | Mg | Mn | Cu | B | Fe | Na |
| A—No $P_2O_5$ | 307 | 2.64 | 0.140 | 2.15 | 2.89 | 0.432 | 81 | 7.3 | 77 | 89 | 525 |
| B—Low $P_2O_5$ | 298 | 2.69 | 0.141 | 2.17 | 2.96 | 0.436 | 90 | 7.0 | 81 | 95 | 529 |
| C—Medium $P_2O_5$ | 300 | 2.69 | 0.142 | 2.06 | 3.02 | 0.431 | 80 | 6.8 | 75 | 94 | 510 |
| D—High $P_2O_5$ | 297 | 2.57 | 0.142 | 2.05 | 3.18 | 0.406 | 99 | 7.1 | 78 | 89 | 552 |

on the central four trees in each plot, or a total of 40 leaves per sample. None of the differences among the treatment means of the elements estimated was significant. However, the trends for potassium, calcium, and magnesium were in the same direction as those in the Valencia plots, and possibly foreshadow differences to come.

*Soil Composition:*—Initially, the exchangeable bases and the exchange capacity of the soil (Table VI) in the Valencia plot area

TABLE VI—THE EXCHANGEABLE BASE AND THE PHOSPHORUS STATUS OF THE TOP SIX INCHES OF SOIL IN THE VALENCIA PLOTS

| Treatments | pH of Mean Acidity | Mean Base Exchange Capacity (ME/100 Gr) | Mean Pounds Per Acre-Six-Inches† | | | | |
|---|---|---|---|---|---|---|---|
| | | | Exchangeable | | | Acid Available P | $H_2O$ Soluble P |
| | | | Ca | K | Mg | | |
| *Samples Collected September 1942* | | | | | | | |
| A—No $P_2O_5$ | 6.0 | 2.63 | 590 | 83 | 88 | 171 | 5.6 |
| B—Low $P_2O_5$ | 6.0 | 2.34 | 520 | 80 | 75 | 181 | 5.3 |
| C—Medium $P_2O_5$ | 5.9 | 2.33 | 542 | 82 | 80 | 181 | 5.4 |
| D—High $P_2O_5$ | 6.0 | 2.42 | 572 | 92 | 89 | 156 | 4.5 |
| *Samples Collected September 1945* | | | | | | | |
| A—No $P_2O_5$ | 6.0 | 2.32 | 602 | 60 | 92 | 178 | 3.6 |
| B—Low $P_2O_5$ | 6.0 | 2.13 | 560 | 70 | 94 | 195 | 6.1* |
| C—Medium $P_2O_5$ | 5.9 | 2.34 | 599 | 60 | 88 | 215* | 9.3** |
| D—High $P_2O_5$ | 5.8 | 2.42 | 624 | 61 | 80 | 251* | 16.3** |

†The top 6 inches was assumed to weigh 2,000,000 pounds per acre.
*These means differ from the A treatment means by statistical odds greater than 19:1 but less than 99:1.
**These differ from A treatment means by odds greater than 99:1.

TABLE VII—THE EFFECT OF PHOSPHORUS FERTILIZATION ON THE PHOSPHORUS STATUS OF THE TOP FOOT OF SOIL IN THE VALENCIA PLOTS (POUNDS PER ACRE-FOOT†)

| Treatment | 1942 Samples | | | | 1946 Samples | | | Total P Mean Gain (1942–1946) | Total P Applied (1942–1946) |
|---|---|---|---|---|---|---|---|---|---|
| | Mean Exchange Ca | Mean P | | | Mean Exchange Ca | Mean P | | | |
| | | Acid-Available | $H_2O$-Sol | Total | | Acid-Available | $H_2O$-Sol | | |
| A—No $P_2O_5$ | 760 | 302 | 10.0 | 801 | 996 | 268 | 4.4 | 73 | 0 |
| B—Low $P_2O_5$ | 644 | 342 | 9.2 | 748 | 856 | 260 | 5.6 | 136 | 87 |
| C—Med. $P_2O_5$ | 688 | 248 | 10.8 | 806 | 892 | 288 | 14.4 | 196 | 241 |
| D—High $P_2O_5$ | 712 | 236 | 10.0 | 696 | 876 | 388 | 23.0 | 577 | 639 |
| Effect of treatment | N.S. | N.S. | N.S. | N.S. | N.S. | * | ** | ** | — |
| L.D. at .05 level. | — | — | — | — | — | 87 | 2.0 | 200 | — |

†An acre-foot was assumed to weigh 4,000,000 pounds.
Statistical symbols:
N. S. = Not significant.
* = Significant (F value between .05 and .01 level).
** = Highly significant (F value above .01 level).
L.D. = Least difference for significance between any two means.

approximated, in most respects, the mean levels found by Peech (20) in Norfolk-type citrus soils surveyed in 1937. However, the exchangeable magnesium level was considerably above average. This may be due to the fact that Peech's samples were obtained before the regular use of magnesium materials in citrus fertilization had gained such

momentum. The acid-available and the water-soluble phosphorus levels were below average. No doubt this is a reflection of the sparing use of phosphatic fertilizer materials in this grove in the period before the experiment was established.

By 1945 the effect of differential treatment on the phosphate status was evident. It appears that water-soluble phosphorus was more closely related to the rate of phosphate fertilization than was acid-available phosphorus.

In April 1942 a series of top-foot soil samples was obtained from the Valencia plots before differential treatment began, and a similar set of samples was obtained in November, 1946. The phosphorus and the calcium status of these two sets of samples is presented in Table VII. Statistical treatment of these data by analysis of variance shows a large error term, suggesting that either the variability of these soil components from plot to plot was great, or that there was a large soil sampling error, or both. In spite of this large variability, the effect of treatment on the phosphorus status in 1946 was highly significant. Again the water-soluble phosphorus was more closely correlated with treatment than acid-available phosphorus. The pH data (not presented) and the exchangeable calcium figures suggest that the high phosphorus plots were slightly more acid than the check plots, but the differences were not of sufficient magnitude to be significant statistically. The same trend is suggested by the data in Table VI. In spite of this trend, the leaf analysis data (Table III) show the presence of more calcium in foliage of the high phosphorus plots in 1947. A similar trend is suggested by the leaf analysis data from the Pineapple orange plots (Table V). This raises the question as to whether calcium in the form of calcium phosphate adds to the supply of available calcium in the soil, or whether high phosphate ion concentration in some way increases the accumulation of calcium in the leaves of the plant.

The data concerning the phosphorus status of the soil from the Pineapple plots show essentially the same trends as those indicated in Table VII. The initial total phosphorus level in this soil was about 300 pounds per acre-6-inches. After 4 years of phosphate fertilization, the heavy phosphate plots contained about 560 pounds per acre of total phosphorus, an increase of 260 pounds per acre. The amount applied was only about 140 pounds when calculated on an acre basis. However, the material was applied by hand and distributed more heavily in the region about the tree where the soil samples were obtained. The water-soluble phosphorus content of soil samples from the various treatments, as in the Valencia plot data, is more closely correlated with the amount of phosphate applied than is the acid-available phosphorus content. There was no significant difference in the acidity of the plots after four years of differential phosphate fertilization.

## Discussion

The results obtained in these experiments to date indicate that heavy superphosphate fertilization did not improve tree growth or fruit production in the two test plots of oranges located on acid sandy

soil. Indeed, the question is raised as to whether any of the superphosphate applied was beneficially used by the experimental trees. A similar question was raised more than 30 years ago by Collison and Walker (6) as a result of studies with citrus trees growing in lysimeter tanks. The fact that the young trees growing in the Pineapple plots for 5 years without formal phosphate additions have grown and fruited in a normal manner on a maximum of about 0.05 pounds per tree per year of added $P_2O_5$ (present in organic N sources) indicates that so far this amount, together with the native supply in the soil, has been adequate to satisfy the requirements of these trees. It seems probable, however, that these trees will eventually show phosphorus stress. An estimate based on analyses given in the literature (28) and upon the assumption that 100 pounds of dry weight of new tree growth plus 200 pounds of fresh weight of fruit were produced by these 5-year-old trees, indicates that the net amount of $P_2O_5$ removed from the soil during the first five years amounted to less than 0.5 pound per tree.

These results appear to agree roughly with Veerhoff's (27) findings that only relatively small amounts of phosphate fertilizer could be used beneficially by peach trees. He established a phosphate fertilizer experiment with peaches in the Sandhills section of North Carolina on virgin soil classified as Norfolk sand. This soil is evidently similar in texture and morphology to the Lakeland series (formerly called Norfolk series) of soils which are common in the Florida citrus belt and on which both of the present citrus fertilizer experiments are located. Although Veerhoff found a definite response of the cover crop to phosphate fertilization, none has so far been noted by inspection of the cover crop (mostly volunteer grasses) in either the Valencia or the Pineapple plots.

The single strength superphosphate used in these experiments is generally used as the source of phosphorus in the mixed fertilizers applied to citrus in Florida. About one-half of this material is gypsum. Appropriate gypsum supplements were added to all but the high phosphate plots to maintain the added calcium sulfate at the same level in all treatments. Had some other phosphatic material such as triple superphosphate been used, so that little gypsum was applied to any of the plots, it is conceivable that the results of these experiments would have been different. This seems unlikely, since fairly large amounts of calcium were supplied to all plots in the form of dolomitic limestone (see Table I).

The soil analyses for total phosphorus presented confirm the findings of others (2, 6, 7, 20) that phosphates accumulate in Florida soils. The acid-available and the water-soluble phosphorus data, together with the leaf analysis data, suggest that this accumulation is associated with increased availability to citrus. This is substantially in agreement with the results of large-scale cooperative experiments with potatoes in commercial producing areas of the Atlantic and Gulf Coasts (8, 14, 22).

Two of the outstanding effects of heavy phosphate fertilization on leaf composition were the depression of copper content and the in-

crease in zinc and manganese. No data are available for these elements on the 1946 samples, when crop size in relation to treatment was the reverse of the 1947 season. The possibility that these effects are simply due to crop size should not be overlooked. However, the copper data seem to conform with the results reported by Forsee and Neller (12), who noted that heavy superphosphate fertilization of orange trees on organic soil induced ammoniation, which is probably due to a deficiency of copper (3). Both Peech (21) and Jamison (16, 17) seem to agree that adding moderate amounts of phosphate does not increase the fixation of copper by Florida soils as measured by extraction with salt solutions or with water. Thus it appears either that exchangeable or water-soluble copper is not a good measure of the availability of copper in the soil, or that phosphate ion or some other constituent of superphosphate reduces the accumulation of copper in the leaves by some mechanism such as antagonism. Similarly, heavy superphosphate fertilization must either increase zinc and manganese availability in the soil, or in some way condition the plant to accumulate more zinc and manganese in its foliage. In view of the fairly large amounts of soluble zinc and manganese applied uniformly to all plots each year, it seems unlikely that the amounts of zinc and manganese (about 0.1 per cent) present in superphosphate (10) could account for the magnitude of difference found.

These fertilizer experiments with citrus illustrate the limitations of moderate-sized random-block design with five or six replications. With the mature bearing trees of the Valencia plots, the yield variance was such that from 11 to 15 per cent difference in yield was required for statistical significance (.05 level) in any given year. In the case of the young trees just coming into bearing in the Pineapple plots, the error term for the 1948 yield data was such as to require a least difference of around 22 per cent for significance between any two treatment means. It is anticipated that as these young trees mature, yield variability will decrease. If these two locations are indicative of the normal yield variability found in reasonably uniform citrus plantings on this common soil type, more elaborate plot techniques will be required to evaluate with certainty and precision relatively small yield effects due to fertilizer treatments.

## Summary

This paper is concerned with the results obtained from two field experiments with oranges on the acid sandy soils of Florida. Three levels of superphosphate fertilization and no phosphate treatment are compared in a mature Valencia orange grove and in a young Pineapple orange grove, the latter planted on virgin soil. Yield and growth data are evaluated for a 6-year period in the Valencia experiment, and for a 4-year period in the Pineapple experiment. In addition, certain effects of treatment on foliage and soil composition are presented.

The results obtained to date indicate that no beneficial use was made of the superphosphate applied to the orange trees in the two experimental blocks. No significant effect on total yield was produced by any of the phosphate levels in either of the two experiments. There

was an indication of a depression in growth associated with heavy superphosphate application as measured by the percentage increase in trunk cross-section in the Valencia, but not in the Pineapple experiment.

Analysis of foliage samples indicates that heavy phosphate fertilization was associated with increased accumulation of phosphate, zinc, and manganese and decreased accumulation of copper in the leaves. There was no significant effect of treatment on the nitrogen, potassium, sodium, boron, or iron content of foliage. There is a suggestion that heavy phosphate fertilization decreases magnesium and increases calcium in the foliage.

Analysis of soil samples from the plots indicates that water-soluble phosphorus reflected with considerable accuracy the rate of phosphate application, but acid-available phosphorus was not so closely related to rate of application. Most of the applied phosphate could be accounted for in the topsoil by analysis for total phosphorus. There were no major effects of treatment on soil acidity or on exchangeable calcium, potassium, or magnesium content.

The effects of phosphate fertilization on certain fruit qualities are considered in an accompanying paper (25).

## Literature Cited


1. Anderssen, F. G. Horticultural services and research. *Farming in South Africa* 22: 260–268. 1947.
2. Bryan, O. C. The accumulation and availability of phosphorus in old citrus grove soils. *Soil Sci.* 36: 245–259. 1933.
3. Camp, A. F., and Fudge, B. R. Some symptoms of citrus malnutrition in Florida. *Fla. Agr. Exp. Sta. Bul.* 335: 1–55. 1939.
4. ———— A resume of feeding and spraying citrus trees from a nutritional viewpoint. *Proc. Fla. State Hort. Soc.* 56: 60–79. 1943.
5. Chapman, H. D. The phosphate of Southern California soils in relation to citrus fertilization. *Calif. Agr. Exp. Sta. Bul.* 571: 1–22. 1934.
6. Collison, S. E., and Walker, Seth S. Loss of fertilizers by leaching. *Fla. Agr. Exp. Sta. Bul.* 132: 1–20. 1916.
7. ———— Citrus fertilizer experiments. *Fla. Agr. Exp. Sta. Bul.* 154: 1–48. 1919.
8. Cummings, R. W. Nutrient status of soils in commercial potato producing areas of the Atlantic and Gulf Coast. I. Background and organization of the study. *Proc. Soil Sci. Soc. Amer.* 10: 240–244. 1945.
9. Curran, H. R., Brunstetter, B. C., and Myers, A. T. Spectrochemical analysis of vegetative cells and spores of bacteria. *Jour. Bact.* 45: 485–494. 1943.
10. Gaddum, L. W., and Rogers, L. H. A study of some trace elements in fertilizer materials. *Fla. Agr. Exp. Sta. Bul.* 290: 1–15. 1936.
11. Finch, A. H., and McGeorge, W. T. Fruiting and physiological responses of Marsh grapefruit trees to fertilization. *Ariz. Agr. Exp. Sta. Tech. Bul.* 105: 428–454. 1945.
12. Forsee, W. T., Jr., and Neller, J. R. Phosphate response in a Valencia grove in the eastern Everglades. *Proc. Fla. State. Hort. Sci.* 57: 110–115. 1944.
13. Friend, W. H. Citrus orchard management in the lower Rio Grande Valley. *Tex. Agr. Exp. Sta. Cir.* 67: 1–56. 1936.
14. Hawkins, A. Nutrient status of soils in commercial potato producing areas of the Atlantic and Gulf Coast. III. Plant responses to fertilization. *Proc. Soil Sci. Soc. Amer.* 10: 252–256. 1945.
15. Innes, R. F. Fertilizer experiments on grapefruit in Jamaica. *Trop. Agric.* 23: 131–133. 1946.

16. Jamison, V. C. The effect of phosphate upon the fixation of zinc and copper in several Florida soils. *Proc. Fla. State Hort. Soc.* 56: 26–31. 1943.
17. ——— The effect of particle size of copper and zinc source materials and of excessive phosphate upon the solubility of copper and zinc in a Norfolk fine sand. *Proc. Soil Sci. Soc. Amer.* 8: 323–326. 1944.
18. Oberholzer, P. C. J. The present status of citrus nutrition in South Africa. *Bul. Dep. Agr. So. Africa* 271: 1–14. 1946.
19. Parker, E. R., and Batchelor, L. D. Effect of fertilizers on orange yields. *Calif. Agr. Exp. Sta. Bul.* 673: 1–39. 1942.
20. Peech, M. Chemical studies on soils from Florida citrus groves. *Fla. Agr. Exp. Sta. Bul.* 340: 1–50. 1939.
21. ——— Availability of ions in light sandy soils as affected by soil reaction. *Soil Sci.* 51: 473–486. 1941.
22. ——— Nutrient status of soils in commercial potato producing areas of the Atlantic and Gulf Coast. II. Chemical data on the soils. *Proc. Soil Sci. Soc. Amer.* 10: 245–251. 1945.
23. ——— Alexander, L. T., Dean, L. A., and Reed, J. F. Methods of soil analysis for soil fertility investigations. *U. S. D. A. Cir.* 757: 1–25. 1947.
24. Rogers, L. H., Gall, O. E., Gaddum, L. W., and Barnette, R. M. Distribution of macro and micro elements in some soils of peninsular Florida. *Fla. Agr. Exp. Sta. Tech. Bul.* 341: 1–31. 1939.
25. Smith, P. F., Reuther, W., and Gardner, F. E. Phosphate fertilizer trials with oranges in Florida. II. Effect on some fruit qualities. *Proc. Amer. Soc. Hort. Sci.* 53: 85–90. 1949.
26. Snedecor, G. W. Statistical Methods. pp. 243–247. Iowa State College Press. 1940.
27. Veerhoff, O. Phosphorus deficiency of peach trees in the Sandhills area of North Carolina. *Proc. Amer. Soc. Hort. Sci.* 50: 209–218. 1947.
28. Webber, H. J., and Batchelor, L. D. The Citrus Industry. Univ. of Calif. Press, Berkeley, Calif. 1943.

# Phosphate Fertilizer Trials With Oranges in Florida
## II. Effect on Some Fruit Qualities

By Paul F. Smith, Walter Reuther, and Frank E. Gardner,
*U. S. Department of Agriculture, Orlando, Fla.*

During the past 6 years differential phosphate fertilization has been applied in randomized block experiments with two varieties of oranges, Valencia and Pineapple, on rough lemon rootstock. The plan of the experiments, along with certain tree responses and soil changes during this period, are described in an accompanying article (15). This report presents some of the observations and measurements of fruit composition from these test blocks.

Briefly, fertilizer mixtures containing approximately 0, 1, 3, and 8 units $P_2O_5$ (in relation to each 4 units of N) were applied differentially (a) to a mature (20 years old in 1942) Valencia orange grove, and (b) to a young Pineapple orange grove which was planted on virgin soil in 1943. The Valencia grove had received sporadic phosphate fertilization from 1923 to 1940 prior to the inception of differential treatments in May 1942. The Pineapple grove, however, had received no application of phosphate during the first year of its existence, until the first differential treatments were made in 1944. The treatments have not caused any significant differences in the total yield of fruits from either variety thus far (15).

Fruit size, rind thickness, percentages of juice, total soluble solids, acidity, ascorbic acid content, and certain chemical constituents (N, P, K, Ca, and Mg) in the juice were determined on certain sampling dates as described below.

## Materials and Methods

Fruit samples were taken at various times during the ripening seasons of the two varieties. Thirty outside fruit were taken from each plot in a band 3 to 8 feet above the ground, so that the sides of the trees furnished fruit approximately in proportion to the density of the crop. The measurements of diameter and rind thickness were made on each fruit after slicing into halves. The juice was extracted by a mechanical press prior to 1948, when an electric reamer was employed. The juice of each lot of 30 oranges was thoroughly mixed and an aliquot, filtered through cheesecloth, was used for all determinations.

The total soluble solids were determined by a Brix hydometer prior to 1948, when a refractometer was used. The acidity was determined by titration with standardized NaOH and expressed as percentage of anhydrous citric acid. Ascorbic acid was measured by titration with 2,6–dichlorobenzenoneindophenol which was standardized against pure vitamin C in the manner described by Bessey and King (2). The chemical elements K, Ca, and Mg were determined by rapid photometric methods adapted from those described by Peech and English (14). Phosphorus and nitrogen were determined by a slight modification of the methods described by Cotton (4).

## Results and Discussion

Fruit samples from the Pineapple variety were analyzed twice during each of the 1946–47 and 1947–48 harvesting seasons. There were no differences that could be attributed to the differential phosphate fertilization, and therefore no data are presented for these measurements.

Samples from the Valencia variety were analyzed twice in 1947, and three times in 1948. The results for the March samplings of each year are presented in Table I.

TABLE I—Summary of Fruit Quality Measurements Made in March for the Years 1947, and 1948 from Valencia Orange Trees on Rough Lemon Rootstock Receiving Four Levels of Phosphate Fertilization Since November 1942 (Each Value Represents a Mean of Five Samples of Thirty Oranges Each)

| Measurement | Units $P_2O_5$ in Fertilizer | | | | L.S.D.† | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 3 | 8 | 0.05 | 0.01 |
| *March 26, 1947, Sampling* | | | | | | |
| Fruit weight (gm) | 220.8 | 225 0 | 223.0 | 228.8 | — | — |
| Rind thickness (mm) | 3.8 | 3.8 | 3.8 | 4.1 | — | — |
| Percentage of juice | 51.3 | 50.9 | 51.8 | 50.7 | — | — |
| Percentage of total soluble solids in juice | 10.96 | 10.86 | 10.82 | 10.64* | 0.29 | — |
| Percentage of citric acid (by weight) in juice | 1.31 | 1.26 | 1.27 | 1.29 | — | — |
| Ratio $\frac{T.S.S.}{C.A.}$ in juice | 8.4 | 8.6 | 8.7 | 8.3 | — | — |
| Ascorbic acid (mg per 100 ml juice) | 40.7 | 38.9* | 36.9** | 33.6** | 1.4 | 2.0 |
| Phosphorus (ppm P in juice) | 161 | 160 | 177** | 185** | 5.7 | 8.0 |
| Nitrogen (ppm N in juice) | 966 | 947 | 988 | 1040* | 59.0 | — |
| *March 17, 1948, Sampling* | | | | | | |
| Fruit weight (gm) | 228.4 | 220.0 | 221.2 | 218.0 | — | — |
| Rind thickness (mm) | 4.6 | 4.3* | 4.3* | 4.1** | 0.23 | 0.32 |
| Percentage of juice | 54.0 | 54.8 | 54.9 | 56.1 | — | — |
| Percentage of total soluble solids in juice | 10.18 | 10.26 | 9.86 | 9.48** | 0.40 | 0.56 |
| Percentage of citric acid (by weight) in juice | 0.98 | 1.00 | 0.95 | 0.93* | 0.058 | — |
| Ratio $\frac{T.S.S.}{C.A.}$ in juice | 1.04 | 10.3 | 10.4 | 10.2 | — | — |
| Ascorbic acid (mg per 100 ml juice) | 44.3 | 44.1 | 42.3 | 38.3** | 1.6 | 2.2 |
| Phosphorus (ppm P in juice) | 140 | 144 | 145 | 152 | — | — |
| Nitrogen (ppm N in juice) | 752 | 772 | 792* | 814* | 32.2 | — |
| Potassium (ppm K in juice) | 1490 | 1536 | 1426 | 1418 | — | — |
| Magnesium (ppm Mg in juice) | 109 | 112 | 107 | 106 | — | — |
| Calcium (ppm Ca in juice) | 73 | 70 | 73 | 73 | — | — |

*Denotes statistical significance at odds of at least 19:1, but less than 99:1.
**Denotes statistical significance at odds of at least 99:1 or greater.
†Least significant difference required between means.

The mean fruit diameter did not differ significantly among treatments either year, although there was a tendency for fruit size to be related to amount of crop in the various treatments. Thus, 1947 being a heavy crop year for the low phosphorus plots, slightly smaller fruit resulted than in the high phosphate plots which had a relatively light crop that year (15). The bearing behavior was reversed in 1948, and the fruit tended to be larger in the low phosphate plots. The thickness of rind tended to vary in direct relation to fruit size, inversely to crop size, and was not directly related to treatment.

The percentage of juice was greater in 1948 than in 1947, which seems to be a result of reaming the fruit samples in 1948. This method of extraction has been shown to give more juice than pressing (7). There was no difference between phosphate treatments in 1947, but there was a trend toward higher juice content in relation to increased phosphate fertilization in 1948. It seems most probable that this is a function of fruit size, and the relation to fertilization is incidental.

In both the 1947 and the 1948 crops there was a significant difference in the total soluble solids of the juice in relation to treatment. The results each year indicated a lowering of soluble solids with increased phosphate fertilization. The magnitude (3 to 7 per cent reduction) of this effect is not great, but was consistently found in all samplings. A similar response by grapefruit to superphosphate on phosphorus-deficient soil in Jamaica was found by Innes (8). The data of Neller and Forsee (13), working with oranges on organic soil in the Everglades of Florida, suggest that above the deficiency level increased phosphate fertilization reduces solids.

The citric acid content was decidedly less in all treatments in the 1948 season than in the previous test season. This may be a seasonal effect, as the only change in fertilization during this time was an increase in the total amount of fertilizer applied (15). Among treatments, there was also a significant lowering of acid in the highest phosphate treatment.

The ratio of total soluble solids to citric acid was lower in 1947 than in 1948, but did not show a significant relationship to the differential treatments when sampled in March. When sampled in January 1948 the ratio increased step-wise with increased phosphate treatment due to the fact that there was less difference in the soluble solids between treatments at this time than had developed by the middle of March. In other words, the total soluble solids increased in the low phosphate treatments at a more rapid rate than in the high phosphate between January and March, 1948, while the drop in citric acid was proportionately the same in all treatments, with the result that a significant difference in the ratio of the two, that was present early in the season, disappeared by midseason.

The constituent that showed the greatest difference due to treatment was ascorbic acid. The five sets of determinations made in 1947 and 1948 showed a mean difference of 14.6 per cent less ascorbic acid in the high phosphate treatment in comparison with the low. Statistically, this difference is highly significant. In 1948 this same magnitude of difference was found in the samplings of January, March, and May. That grapefruit may respond in the same way is suggested by the work of Innes (8), where the overcoming of phosphorus deficiency was accompanied by a decrease in ascorbic acid in the fruit.

In 1947 the phosphorus content of the juice tended to increase with increased phosphate fertilization. In 1948 a slight, but not significant, gradient in phosphorus content was found. This may suggest that there is some interrelationship of the phosphorus content of the juice with size of crop, alternate bearing cycle, and phosphate fertilizer level. Thus in 1947, when a heavy crop was produced on the low

phosphate plots and a light crop on the heavy phosphate plots (15), a highly significant increase in phosphorus paralleling treatment was found in the juice. In 1948, when the reverse relation in crop size occurred, an increase in phosphorus in the juice was observed in the same direction, but it was not large enough to show significance. The May 1948 sampling showed that the phosphorus content of all treatments had increased from about 145 p p m in March (Table I) to about 165 p p m, which indicates that phosphorus continued to enter the juice for a considerable time after fruit maturity had been reached. The other elements (N, K, Ca and Mg) showed virtually no change in amount during this time.

The nitrogen content of the juice was found to be significantly greater in the highest phosphate treatment both in 1947 and in 1948. There seems to be no apparent explanation for this response, as no difference was found in the leaf nitrogen either year, although other constituents of the leaf did vary with treatment (15).

The amounts of calcium, magnesium, and potassium in the juice showed no significant differences among treatments.

The interrelationships of some of the constituents of citrus juices have been pointed out by various investigators. Anderssen (1) shows several correlations between different juice components from his experiments in Africa and refers to other investigations on the subject. More recently Jones and co-workers (9, 10, 11) have shown an inverse relationship (in some cases no apparent relation) between nitrogen content and ascorbic acid content of grapefruit and oranges. Correlation coefficients for some of the possible combinations in the present study are shown in Table II. An inverse relationship between phosphorus and ascorbic acid in juice was apparent for both years. A similar relationship in Navel oranges in California has been found by

TABLE II—Correlation Coefficients on Juice Constituents of Valencia Oranges Grown With Four Levels of Phosphate Fertilization

| Function | Coefficient | |
|---|---|---|
| | Mar 26, 1947 | Mar 17, 1948 |
| r Phosphorus—Ascorbic acid | −0.812** | −0.533* |
| r Phosphorus—Solids | −0.326 | −0.490* |
| r Phosphorus—Citric acid | −0.039 | −0.232 |
| r Phosphorus—Nitrogen | +0.669** | +0.496* |
| r Nitrogen—Ascorbic acid | −0.633** | −0.552* |
| r Nitrogen—Solids | −0.098 | −0.459* |
| r Nitrogen—Citric acid | +0.003 | +0.023 |
| r Solids—Ascorbic acid | +0.485* | +0.807** |

*Significance at odds greater than 19:1.
**Significance at odds greater than 99:1.
18 degrees of freedom exist for each correlation.

Jones and Parker (12). Likewise, an inverse relation was found to exist both years between nitrogen and ascorbic acid. There is a tendency toward an inverse relation between nitrogen and solids. Ascorbic acid varied in direct relation to total soluble solids. Nitrogen and phosphorus showed a positive relation to each other. There was a tendency, in 1948, toward an inverse relation between phosphorus

content and citric acid content of the juice. Such a relation has previously been found by various workers (1, 12).

In view of the studies that have been made in widely separated localities, caution should be exercised in generalizing from simple correlations of two variables in citrus juice. It is apparent that numerous interacting factors are involved in determining the level of any given variant. Thus, for example, certain results in Africa (1) and California (12) show that with Navel oranges an inverse relation exists between the phosphorus content and nitrogen content of the juice. Analyses made on the data of Fudge (6) with Pineapple oranges and Excelsior grapefruit in Florida show a nonsignificant association of these elements in the orange juice and a positive correlation in the grapefruit. The present findings with Valencia oranges show a positive correlation of the accumulation of these two elements in both 1947 and 1948. Similarly, it was found in Africa (1) that an increase in juice nitrogen was associated with increased solids in Navel oranges. In the present studies and in measurements with grapefruit in Arizona (10) the opposite condition has prevailed. It should be emphasized that the correlations between the various constituents shown in Table II were obtained under conditions of differential phosphate application, the only cultural treatment differentially varied in this experiment.

The increased application of phosphate tends to reduce the internal fruit quality. The differences found probably would not be detectable by taste, however, the reduction in ascorbic acid would be an appreciable economic factor since fruit that is used in canneries must have a certain ascorbic acid content. Valencia oranges frequently fail to meet this requirement in the latter part of the season, thus making it undesirable to unnecessarily reduce the ascorbic acid content.

The highest phosphate level used was chosen because it was widely used in commercial groves at the time the experiment was started. A further increase in applied phosphate would logically accentuate the differences found. This is indicated, in fact, by work in the Florida Everglades (13) where the solids were reduced by using twelve units of $P_2O_5$ in the fertilizer as compared with six units.

## Summary

Fruit samples from young Pineapple orange and mature Valencia orange trees, grown on Lakeland sand (formerly classified as Norfolk sand) and subjected to four levels of phosphate fertilization, were analyzed for certain physical and chemical characteristics. These include fruit weight and diameter, rind thickness, percentage of juice, and the percentages of total soluble solids, anhydrous citric acid, ascorbic acid, phosphorus, nitrogen, potassium, magnesium, and calcium in the juice. The phosphate treatments were: 0, 1, 3, and 8 units of $P_2O_5$ to each 4 units of nitrogen applied.

The fruit produced as the first two crops by the 5-year-old Pineapple orange trees showed no response to differential phosphate fertilization.

The fruit produced by the 25-year-old Valencia trees, which were

placed under differential phosphate fertilization in 1942, showed in 1947 and 1948 that with increased amounts of applied phosphate (a) total soluble solids, citric acid, and ascorbic acid were lowered; (b) the phosphorus and nitrogen in the juice were slightly increased; and (c) no other measured property of the fruit or juice was changed to an appreciable extent.

Significant positive correlations were found between juice content of nitrogen and of phosphorus, and also between total soluble solids in the juice and ascorbic acid content. Inverse correlations were found between phosphorus and ascorbic acid, phosphorus and total soluble solids, nitrogen and ascorbic acid, and nitrogen and total soluble solids.

In these tests, the changes accompanying increased phosphate fertilization are not considered beneficial to fruit quality. The lowering of total soluble solids, citric acid, and ascorbic acid tends to be deleterious to the internal fruit quality of Valencia oranges.

## Literature Cited

1. Anderssen, F. G. Citrus manuring — its effect on cropping and on the composition and keeping quality of oranges. *Jour. Pom. and Hort. Sci.* 15(2): 117–159. 1937.
2. Bessey, O. A., and King, C. G. The distribution of vitamin C in plant and animal tissues, and its determination. *Jour. Biol. Chem.* 103: 687–698. 1933.
3. Chapman, H. D., Brown, S. M., and Liebig, G. F. Some effects on citrus fruit quality of nitrogen, phosphorus and potassium. *Calif. Citrog.* 28 (8, 9): 198, 211, 230 and 246. 1943.
4. Cotton, R. H. Determination of nitrogen, phosphorus, and potassium in leaf tissue. *Ind. Eng. Chem., Anal. Ed.,* 17(11): 734–738. 1945.
5. Finch, A. H., and McGeorge, W. T. Studies of grapefruit fertilization in Arizona. *Proc. Amer. Soc. Hort. Sci.* 37: 62–67. 1939.
6. Fudge, B. R. The mineral composition of citrus juice as influenced by soil treatment. *Proc. Fla. State Hort. Soc.* 54: 4–12. 1941.
7. Harding, P. L., and Fisher, D. F. Seasonal changes in Florida grapefruit. *U. S. D. A. Tech. Bul.* 886. 1945.
8. Innes, R. F. Fertilizer experiments on grapefruit in Jamaica. *Trop. Agric.* 23: 131–133. 1946.
9. Jones, W. W., Van Horn, C. W., Finch, A. H., Smith, M. C., and Caldwell, E. A note on ascorbic acid: nitrogen relationships in grapefruit. *Science* 99: 103–104. 1944.
10. Jones, W. W., Van Horn, C. W., and Finch, A. H. The influence of nitrogen nutrition of the tree upon the ascorbic acid content and other chemical and physical characteristics of grapefruit. *Ariz. Exp. Sta. Tech. Bul.* 106. 1945.
11. Jones, W. W., and Parker, E. R. Ascorbic acid-nitrogen relations in Navel orange juice as affected by fertilizer applications. *Proc. Amer. Soc. Hort. Sci.* 50: 195–198. 1947.
12. ———— Orange fruit quality and fertilizers in California. *Proc. Amer. Soc. Hort. Sci.* 53: 91–102. 1949.
13. Neller, J. R., and Forsee, W. T., Jr. Fertilizer experiments in an orange grove in the eastern Everglades. *Proc. Fla. State Hort. Soc.* 54: 1–4. 1941.
14. Peech, M., and English, L. Rapid microchemical soil tests. *Soil Sci.* 57(3): 167–195. 1943.
15. Reuther, W., Gardner, F. E., Smith, P. F., and Roy, W. R. Some phosphate fertilizer trials with oranges in Florida. I. Effects on yield, growth leaf and soil composition. *Proc. Amer. Soc. Hort. Sci.* 53: 71–84. 1949.
16. Young, H. D. Effect of fertilizers on the composition and quality of oranges. *Jour. Agr. Res.* 8(4): 127–138. 1917.

# Effects of Nitrogen, Phosphorus, and Potassium Fertilizers and of Organic Materials on the Composition of Washington Navel Orange Juice[1]

By WINSTON W. JONES and E. R. PARKER, *University of California Citrus Experiment Station, Riverside, Calif.*

THE object of the work reported in this paper was to determine the influence of nitrogen, phosphorus, and potassium fertilizers, and of manure and winter covercrops on the composition of the juice of the Washington Navel orange. The use of these fertilizer materials is a common practice in California groves, although experiments (11) have shown no apparent yield response as a result of the use of phosphorus and potassium.

Young (19) reported that nitrogen was the only fertilizer that exercised a specific effect on the composition of oranges. The possible interaction between nitrogen and phosphorus apparently was not considered. Finch and McGeorge (6) observed that yield of fruit and quality of grapefruit in Arizona were closely related to nitrogen nutrition, and that there was a marked inverse relation between the nitrogen content and the phosphorus content of the fruit. Investigating the seasonal supply of nitrogen to grapefruit trees in Arizona, Jones, Van Horn, and Finch (10) found that the quality of the fruit could be varied by the control of the nitrogen supply without markedly affecting the phosphorus content.

Anderssen (1), in South Africa, found that the acid content of orange juice was correlated negatively with the total phosphorus content and positively with the nitrogen content, and that the nitrogen and the phosphorus contents of the juice were inversely related. By obtaining the partial regression coefficients of the total phosphorus and the nitrogen content on titratable acidity of the juice, he obtained indications that the negative correlation between acid content and total phosphorus was direct, while the positive correlation of acid content and nitrogen was indirect, being brought about by a depression of phosphorus absorption. Anderssen (1) and other workers in South Africa also reported a positive correlation between the acid content and the potassium content of the juice.

Takahashi (16, 17, 18) reported that sprays of phosphoric acid and of lead orthoarsenate lowered the acid content of the fruit, whereas sprays of potassium carbonate caused an increase in acid content. Chapman *et al* (4, 5) found that in orange trees growing in sand and solution cultures a high phosphorus supply was related to decreased fruit acid and good fruit quality, while high potassium supply was correlated with increased fruit acid and poor fruit quality. They detected no influence of nitrogen on quality.

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[1]Paper No. 595, University of California Citrus Experiment Station, Riverside, California.

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Forsee and Neller (7) observed that the quality of Lue Gim Gong oranges growing on phosphate-deficient muck soil in the eastern Everglades of Florida was poor. The fruit was of a bright-yellow color and of coarse external and internal texture. The rind was thick and the juice somewhat low in total solids and distinctly high in acid. These conditions were remedied by the application of phosphatic fertilizers.

Innes (8) found that, in Jamaica, the fruit of low-yielding grapefruit trees growing on phosphate-deficient soil was high in total acid and ascorbic acid, and that fertilization reduced both. The fruit of low-yielding potash-deficient trees was low in total acid and ascorbic acid, and both were increased by application of potash fertilizers. Sites (14) has shown that under conditions of potassium deficiency the addition of this element increased both the total acidity and the ascorbic acid content of Duncan grapefruit juice. More recently, Smith, Reuther, and Gardner (15) have shown that total soluble solids, total acidity, and the ascorbic acid in the juice of Valencia oranges grown in Florida was decreased by application of phosphates, although yields were not significantly affected.

Studies of the influence of phosphorus and potassium on fruit quality have been underway at the Citrus Experiment Station at Riverside for many years. The earlier work did not yield consistent results, but it was evident that such differences in fruit quality as may have been caused by the application of those elements were of small dimensions. The work of Parker and Batchelor (11) and of Parker, Batchelor, and Jones (to be reported) shows no increase in yield and no improvement in commercial grade of fruit as a result of the use of phosphate or potash fertilizers. It is evident that the quality of field-grown citrus fruits is variable, and that adequately designed field plots and careful sampling are necessary to demonstrate such small differences as may be attributed to the elements under consideration, especially when they are not factors which limit the volume of crop produced. The first significant results were obtained in 1942 in the course of a study of sampling and other methods suitable for studying the effects on fruit quality of potassium and organic matter applications (Parker, unpublished) and led to subsequent, more extensive studies.

## Material and Methods

*Experimental Material:*—For these studies fruit samples from two field fertilizer experiments with Washington Navel oranges on sweet orange rootstock were used. The first experiment is part of a complex, long-term experiment in a grove located at the University of California Citrus Experiment Station, Riverside, California, on Romona loam soil. This grove has been described elsewhere (3). The trees in this grove were planted in 1917, and differential fertilizer applications were begun in 1927. The treatments discussed in the present paper have been continued without change, except that the annual applications of nitrogen were increased from 1 pound to 3 pounds per tree in 1939–40. Each plot consists of a row of eight trees, with guard rows on each side. Each treatment is replicated four times. For these studies, 12

treatments, as listed in Table I, were chosen. All plots given these treatments have received the same amount of nitrogen (3 pounds N per tree each year since 1939) in the fertilizer, except those of treat-

TABLE I—SELECTED TREATMENTS USED IN THE RIVERSIDE EXPERIMENT

| Treatment | Cover-crop* | Fertilizer Ingredients Applied Since 1939 (Pounds/Tree/Year)† | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| 6. No fertilizer | Yes | 0 | 0 | 0 |
| 2. Urea | No | 3 | 0 | 0 |
| 3. Urea, phosphorus | No | 3 | 1 | 0 |
| 4. Urea, phosphorus, potassium | No | 3 | 1 | 1 |
| 5. Urea, potassium | No | 3 | 0 | 1 |
| 18. Urea | Yes | 3 | 0 | 0 |
| 8. Urea, phosphorus | Yes | 3 | 1 | 0 |
| 9. Urea, phosphorus, potassium | Yes | 3 | 1 | 1 |
| 11. Urea, potassium | Yes | 3 | 0 | 1 |
| C. Urea, manure | Yes | 3 | 0.74‡ | 3.01‡ |
| 31. Manure | Yes | 3 | 1.49‡ | 6.03‡ |
| 23. Calcium nitrate | Yes | 5 | 0 | 0 |

*Winter covercrop of melilotus or vetch with a nonlegume (mustard or grain).

†Phosphorus was derived from treble-superphosphate, and potassium from potassium sulphate. The source of nitrogen is indicated in the table. From 1927 to 1939, nitrogen applications were at the rate of 1 pound N per tree annually.

‡Approximation; based on analysis of samples part of the years.

ment 6, which have never received fertilizers, and of treatment 23, which have received 5 pounds of nitrogen per tree annually since 1939. As shown in Table I, the applied nitrogen has been derived from urea in all treatments except 31 (manure), 23 (calcium nitrate), and treatment C (urea and manure). One application of each fertilizer material was made each year except in treatment 23, in which the total quantity was applied in two applications each year. In some of the treatments the plots have been clean-cultivated the entire year, but in others winter covercrops have been grown.

The second experimental grove of Washington Navel oranges used in these studies is located at Claremont, California, on Hanford gravelly loam. The grove is clean-cultivated, and the trees were approximately 40 years old when the experiment was started, in 1937. This trial is laid out in the form of a Latin square, with six treatments, each replicated six times. Each plot consists of four trees, and there are two guard rows between plots. Experimental applications of fertilizers have been made for 10 years. The experimental applications are in addition to blanket applications of various fertilizers, which apply no more than 2 pounds of actual nitrogen to each tree per year. Part of the blanket application has been made in the form of manure and part in the form of various chemical nitrogen carriers. The experimental applications, none of which has increased yields over the check treatments, are listed in Table II.

Detailed observations on the quality of fruits from both experimental orchards were made at two periods in the spring of 1947. Parallel studies had been made at one date on the crop harvested in the spring of 1946. In 1942 a very intensive study was made of a smaller group of treatments in the Riverside trials, as mentioned earlier. The fruit-

TABLE II—TREATMENTS USED IN THE CLAREMONT EXPERIMENT

| Treatment* | Fertilizer Ingredients Applied Since 1944 (Pounds/Tree/Year)† | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| None (check) | 0 | 0 | 0 |
| N | 4 | 0 | 0 |
| P | 0 | 10 | 0 |
| N, P, K | 4 | 4 | 4 |
| K | 0 | 0 | 10 |
| Manure | 4 | 1.97‡ | 8.03‡ |

*Approximately 2 pounds of nitrogen per tree per year were applied by grower as blanket applications of manure or chemical nitrogen carriers, in addition to all treatments (see text).
†Amounts are as indicated since 1944. No applications were made in 1942 and 1943. The amounts applied experimentally from 1937 to 1941 were one-half of those indicated. Nitrogen was applied as calcium nitrate, urea, and ammonium sulphate in various years; phosphate was applied as treble-superphosphate, and potash, as potassium sulphate. The plots are clean-cultivated.
‡Approximation; based on analysis of similar materials.

quality data obtained at these periods of observation are in substantial agreement. The data presented here are those of the second sampling of 1947, for which analyses of the inorganic constituents of the juice have been made.

*Fruit Sampling:*—On the basis of previous experience, the following procedure was adopted in sampling the fruit of these experiments. For each period, the fruits of three typical trees per plot were sampled. In the Riverside experiment the fruits of one tree of each plot were sampled on one day, and the observations on those samples were made immediately. Two days later, the fruits of the second tree of each plot were sampled, and observations were made on those samples. As soon as possible after the second set of samples had been taken, the fruits of the third tree of each plot were sampled and subjected to testing. Similar procedure was followed in sampling the fruit of the Claremont experiment, except that the fruits of the second and third trees in each plot were sampled on the same day.

The actual dates of sampling for the Riverside experiment were March 3, 5, and 10, 1947; and for the Claremont experiment, March 12 and 17, 1947. These picking dates are in the approximate middle of the normal harvest season. Any possible effects of differences in dates of picking the fruit of individual trees were ignored in the analysis of the data, since in each trial they are confounded with within-plot variation. All treatments in each experiment are equally subjected to whatever effects they introduce.

The fruits chosen for study were of almost uniform size. Except as noted, only those fruits which would pass through a 200 ring (200 fruits per packed box), 2.75 inches in diameter, but which would not pass through a 252 ring, 2.50 inches in diameter, were used. The fruits picked were of the size which was judged to be the mode of the size distribution. The weights and volumes of each sample of fruit (Table III) indicated that fruits of about equal size were obtained in all samples except those of no-fertilizer treatment of the Riverside experiment, for which the fruits were somewhat larger. This treatment produced a very small crop, since nitrogen is a limiting element in fruit production in this treatment (11).

In picking each sample, six fruits were taken from each quadrant of the tree. These six fruits were picked from a cone-shaped zone, at shoulder height, in order to provide a suitable sample of inside and outside fruit. Since fruits of three trees in each plot were sampled, the number of fruits taken was 72 per plot at each sampling period. Each treatment of the Riverside experiment (four replications) provided a total of 288 fruits, and each treatment in the Claremont experiment (six replications) provided a total of 432 fruits for each period. In sampling, one man picked all the plots of each replication series of an experiment. Thus variations due to the differences in the sampling procedures of individual men were confounded with block effects in the statistical analysis. The fruits from each tree were bagged separately and subjected to laboratory examination.

*Laboratory Procedure:*—In the laboratory the fruits were weighed in air and under water. They were then spread on a large table, measured in two dimensions, and compared as to color, conformation, and rind texture. The weight, volume, length, and width of the fruits were determined. They were next cut transversely and additional observations were made.

After the fruit had been cut, the juice was extracted with an electric reamer fitted with a vibrating screen and was then passed through a 20-mesh sieve with gentle stirring until drainage ceased. The weight, volume, pH, Brix, acid, and ascorbic acid of the juice were obtained for each tree sample of 24 fruits. Several inorganic constituents were determined on a composite of equal volumes of juice of fruit of each of the three trees for each plot. All data presented (Table III) are treatment means.

*Analytical Methods:*—Volume was determined by water displacement; pH, by glass electrode; Brix, by use of a refractometer graduated to read in percentage of sucrose; total acid (reported as citric), by titration with sodium hydroxide and correction for specific gravity of juice; ascorbic acid, by visual titration with 2,6 dichlorobenzenone-indophenol; nitrogen, by the micro-Kjeldahl method; phosphorus (as phosphate), by the colorimetric method (2); calcium (as calcium oxalate), by titrating against $KMnO_4$ (2); potassium (as potassium cobaltinitrite), was determined by the method of Peech *et al* (12). Statistical studies were made by analysis of variance.

## Results and Discussion

The mean results of observations are presented in Table III.[2] Until the effects of covercrops are discussed, comparisons should generally be made within the data for the separate experiments.

*Weight (1) and Volume (2) of Fruit:*—The fruits were ring-picked; differences in weight and volume are therefore related to variations within ring sizes. Since the no-fertilizer treatment of the Riverside experiment did not provide sufficient fruit of the desired size, the mean

[2]Numbers in parentheses in the following headings refer to respective columns of Table III.

TABLE III—EFFECTS OF FERTILIZERS ON WASHINGTON NAVEL ORANGE FRUIT FROM RIVERSIDE AND CLAREMONT EXPERIMENTS (FRUIT PICKED MARCH, 1947)

| Treatment | Fruit Means (1) Weight (Grams) | (2) Volume (Ml) | (3) Ratio of Length to Width | (4) Specific Gravity | Juice (5) Volume (Per Cent) | (6) pH | (7) Total Acid as Citric (Per Cent) | (8) Total Soluble Solids (Per Cent) | (9) Soluble Solids-to-Acid Ratio | (10) Ascorbic Acid (Mg/100 Ml) | (11) Mineral Constituents (Mg/100 Ml) N | (12) P | (13) K | (14) Ca |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Riverside Experiment—With Covercrop** | | | | | | | | | | | | | | |
| No fertilizer | 179.3 | 199.3 | 1.058 | 0.900 | 36.4 | 3.37 | 1.06 | 13.87 | 13.06 | 76.53 | 119.9 | 27 80 | 199.7 | 20.00 |
| N | 140.1 | 162.2 | 1.046 | 0.866 | 30.2 | 3.42 | 1.05 | 14.01 | 13.36 | 66.24 | 171.9 | 21.83 | 162.3 | 20.60 |
| N,P | 144.3 | 164.1 | 1.059 | 0.879 | 32.3 | 3.42 | 1.01 | 14.03 | 13.94 | 63.63 | 178.2 | 23.63 | 168.1 | 18.90 |
| N,P,K | 143.4 | 164.7 | 1.052 | 0.871 | 31.8 | 3.44 | 1.14 | 14.03 | 12.34 | 66.24 | 182.0 | 22.34 | 184.9 | 13.81 |
| N,K | 143.1 | 165.3 | 1.052 | 0.865 | 31.1 | 3.41 | 1.17 | 14 28 | 12.25 | 70.43 | 169.4 | 17.99 | 205.9 | 15.79 |
| Mean of four treatments | 142:7 | 164.1 | 1.052 | 0.870 | 31.3 | 3.42 | 1.09 | 14.09 | 12.97 | 66.63 | 175.4 | 21.45 | 180.3 | 17.28 |
| N and manure | 140.1 | 162.6 | 1.057 | 0.862 | 30.9 | 3.36 | 1.12 | 14.11 | 12.61 | 68.81 | 168.4 | 22.17 | 188.7 | 16.28 |
| Manure | 147.1 | 169.5 | 1.063 | 0.868 | 32.0 | 3.47 | 1.10 | 13.47 | 12.30 | 63.72 | 159.3 | 19.66 | 195.8 | 13.32 |
| High N | 139.6 | 161.7 | 1.051 | 0.863 | 30.6 | 3.49 | 1.00 | 13.82 | 13.87 | 63.50 | 180.6 | 22.43 | 161.6 | 18.94 |
| L.S.D.‡—at 5 per cent | — | — | *0.015* | *0.012* | *2.0* | *0.04* | *0.08* | *0.60* | *0.88* | *3.44* | *12.2* | *2.33* | *16.2* | *1.90* |
| —at 1 per cent | — | — | *0.021* | *0.016* | *2.6* | *0.05* | *0.11* | *0.81* | *1.18* | *4.62* | *16.4* | *3.13* | *21.6* | *2.56* |
| *Riverside Experiment—Without Covercrop** | | | | | | | | | | | | | | |
| N | 143.3 | 163.7 | 1.040 | 0.875 | 31.6 | 3.42 | 1.10 | 14.26 | 13.07 | 66.49 | 181.7 | 17.78 | 202.9 | 18.95 |
| N,P | 151.2 | 172.0 | 1.049 | 0.879 | 32.7 | 3.40 | 1.04 | 14.11 | 13.67 | 62.09 | 179.9 | 22.90 | 169.6 | 15.30 |
| N,P,K | 144.6 | 165.8 | 1.054 | 0.872 | 32.5 | 3.38 | 1.17 | 14.60 | 12.53 | 65.88 | 187.6 | 21.32 | 204.1 | 13.68 |
| N,K | 141.7 | 163.4 | 1.059 | 0.867 | 31.0 | 3.36 | 1.17 | 14.47 | 12.44 | 67.05 | 183.4 | 22.50 | 221.8 | 16.34 |
| Mean of four treatments | 145.2 | 166.2 | 1.051 | 0.873 | 31.9 | 3.39 | 1.12 | 14.36 | 12.93 | 65.38 | 183.2 | 21.12 | 199.6 | 16.07 |
| L.S.D.‡—at 5 per cent | — | — | *0.015* | *0.012* | *2.0* | *0.04* | *0.08* | *0.60* | *0.88* | *3.44* | *12 2* | *2.33* | *16.2* | *1.90* |
| —at 1 per cent | — | — | *0.021* | *0.016* | *2.6* | *0.05* | *0.11* | *0.81* | *1.18* | *4.62* | *16.4* | *3.13* | *21.6* | *2.56* |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Claremont Experiment—Without Covercrop*† | | | | | | | | | |
| Check | 140.3 | 156.4 | 1.016 | 0.897 | 36.2 | 3.45 | 1.23 | 14.04 | 11.47 | 71.54 | 175.2 | 19.36 | 196.5 | 18.80 |
| N | 141.9 | 158.8 | 1.012 | 0.894 | 35.2 | 3.45 | 1.40 | 14.41 | 10.38 | 72.09 | 214.2 | 17.48 | 231.8 | 19.68 |
| P | 147.8 | 162.1 | 1.024 | 0.912 | 39.6 | 3.49 | 1.13 | 13.73 | 12.19 | 62.53 | 178.0 | 22.66 | 201.0 | 18.88 |
| K | 141.4 | 156.7 | 1.017 | 0.902 | 37.4 | 3.45 | 1.30 | 14.23 | 11.07 | 71.39 | 175.9 | 19.42 | 228.4 | 17.29 |
| N,P,K | 144.4 | 159.5 | 1.023 | 0.905 | 37.3 | 3.48 | 1.35 | 14.34 | 10.66 | 66.18 | 218.4 | 21.05 | 243.0 | 18.56 |
| Manure | 143.4 | 159.2 | 1.019 | 0.901 | 37.1 | 3.46 | 1.29 | 14.14 | 10.48 | 66.79 | 181.8 | 19.90 | 227.2 | 19.11 |
| L.S.D.‡—at 5 per cent | — | — | *n. s.* | *0.008* | *1.2* | *n. s.* | *0.09* | *0.43* | *0.65* | *4.76* | *38.8* | *2.36* | *16.6* | *n. s.* |
| —at 1 per cent | — | — | — | *0.010* | *1.6* | — | *0.13* | *0.59* | *0.88* | *6.50* | *52.9* | *3.23* | *22.6* | — |

*See Table I for treatments at Riverside.
†See Table II for treatments at Claremont.
‡Least significant differences between any two treatment means. To compare two means of four treatments divide L.S.D. by 2. Nonsignificance of differences between means is indicated by "*n. s.*"

size of the fruit used for this treatment was somewhat larger than that used for the other treatments.

*Ratio of Fruit Length to Fruit Width (3):*—This ratio indicates the general shape of the fruit. The application of phosphorus and potassium with nitrogen is related to fruit that is very slightly longer in relation to width than that resulting from the use of nitrogen alone. Manure had the same effect. Fruits at Riverside were more elongated than those at Claremont.

*Specific Gravity of Fruit (4) and Volume of Juice (5):*—The no-fertilizer treatment in the Riverside experiment produced fruit having the greatest specific gravity and the largest percentage of juice. These effects are accompanied by very low nitrogen concentrations in the juice. The relationships appear to be indirect, however, since, as will be pointed out later, the juice of fruits of this treatment contained the greatest concentration of phosphorus. Among the Riverside treatments using equal amounts of nitrogen, those which also used phosphorus produced fruit of slightly greater specific gravity and slightly more juice content. In the treatments without covercrop, the additional use of phosphorus fertilizers increased the volume of juice 3.5 per cent, while in those employing covercrops the increase was 7 per cent. On the other hand, the elimination of nitrogen fertilization resulted in an increase of 20.5 per cent in juice content. It is interesting to note that in this trial liberal applications of nitrogen had no effect on juice content or specific gravity, as compared with moderate applications. Manure, as compared with calcium nitrate as sources of nitrogen, also had no effect.

In the Claremont trials the use of liberal nitrogen, as compared with moderate nitrogen (the check treatment), also had no effect on specific gravity of fruit or juice content. Heavy phosphorus applications increased both of these criteria, however; the increase in volume of juice was 9.4 per cent. Manure increased the juice content and specific gravity of the fruit slightly over that of the nitrogen treatment in the Claremont experiments.

Anderssen (1) has found no effect of phosphorus on the percentage of juice of peeled fruit. It is probable that the increase in juice percentage reported in the present studies is due to the effects of phosphorus absorption on the thickness of peel, as reported by Forsee and Neller (7). Data obtained in 1948 on fruit from our experiments indicate this to be the case.

Potassium applications, or the growing of covercrops, apparently had no effect on the volume of juice or the specific gravity of the fruit.

*The pH of Juice (6):*—Citrus juice is highly buffered (13); nevertheless, the pH of the juice differs significantly between the treatments of these experiments. Very low nitrogen (at Riverside) resulted in a low pH of the juice. Manure alone, and high nitrogen, resulted in a high pH of the juice. This relationship between high nitrogen and high pH has also been reported for grapefruit (10).

*Total Acid (7) and Total Soluble Solids (8) of Juice:*—In each experiment there was a consistent tendency for the acid of the juice to be

reduced slightly where phosphorus was applied; however, where potassium was applied with phosphorus, the phosphorus apparently had no effect in lowering the juice acid. Application of potassium, alone or with phosphorus, tended to increase the acid. At Claremont, nitrogen alone resulted in an increase of acid over the check treatment. This is probably related to decreased phosphorus content (see Table III). Manure had no significant effect on acid in most comparisons, but at Claremont resulted in lower total acid than the nitrogen treatments.

Soluble solids were not significantly changed by fertilizer applications in the non-covercropped plots at Riverside. In the covercropped plots at that location manure alone decreased soluble solids as compared to the means of four treatments which received inorganic fertilizers. The values resulting from the use of manure alone were only slightly less than those obtained with fruit from the no-nitrogen and high-nitrogen treatments. In the Claremont trials, phosphorus application gave lower soluble solids than the use of either nitrogen or potassium alone, or the application of N, P, and K.

*Ratio of Soluble Solids to Acid (9):*—The ratio of soluble solids to acid in the fruit was significantly affected at Riverside, the application of potassium resulting in a lower ratio. At Claremont application of potassium had no significant effect. The application of phosphorus resulted in a tendency toward a higher ratio at Riverside, and in a significantly higher ratio at Claremont. Manure slightly decreased the ratio, in comparison with the nitrogen covercrop treatment in the Riverside experiment, and resulted in considerably lower values than those obtained in the treatment receiving high nitrogen from an inorganic source.

*Ascorbic Acid in Juice (10):*—An inverse relationship between ascorbic acid and nitrogen in the juice, as determined in fruit of the first period of sampling of the Riverside plots in 1947, has been reported (9). The data for the second sampling period, reported here, showed the same relationship existing when all the treatments were considered. There was no such correlation for the Claremont experiments, in which all plots received a moderate quantity of nitrogen. Neither was there a correlation at Riverside when only those plots receiving the same amount of nitrogen were considered. In the latter group of plots at Riverside, as well as in the Claremont plots, other factors caused significant variations in the ascorbic acid content of the juice. The application of phosphorus tended to reduce the ascorbic acid concentration. The addition of potassium apparently counteracted this effect. When used alone, potassium appears to have slightly increased ascorbic acid concentration in fruit of the covercropped plots at Riverside, and tended to do so in other comparisons. Manure, when used alone, decreased ascorbic acid.

*Nitrogen in Juice (11):*—The nitrogen concentration in the juice was increased by nitrogen applications in both sets of plots. In the Claremont plots, where the amount of nitrogen applied was greater, the amount of nitrogen in the juice was likewise greater. Where the

application of nitrogen was the same, the amount of nitrogen in the juice was not changed by the application of phosphorus and/or potassium. At Riverside, the application of manure significantly decreased the nitrogen in the juice.

*Phosphorus in Juice (12):*—The greatest phosphorus concentrations in the juice were found in fruit of the Riverside plots which received no nitrogen. In those treatments using equal amounts of nitrogen in the fertilizer, the application of phosphorus resulted in a slight increase of phosphorus in the juice. The application of potassium along with phosphorus caused a slight decrease in phosphorus in the juice; the use of potassium alone caused an even larger decrease in phosphorus. At Claremont, large applications of nitrogen decreased the phosphorus content of the juice, and applications of phosphorus were reflected in the phosphorus content of the juice.

*Potassium in Juice (13):*—The potassium content of the juice was high in fruit from the Riverside plots which received no fertilizer in comparison with the plots which received only nitrogen. Results of the no-nitrogen treatment are not comparable to those of other treatments because of the extreme nitrogen deficiency. Comparisons between those treatments which employed nitrogen indicate that an application of potassium in the fertilizer brought about an increase of potassium in the juice. In these Riverside plots the application of phosphorus with potassium reduced the amount of potassium in the juice, as compared with that in juice from the potassium treatment. This does not seem to be the case for the Claremont plots, but in those plots heavy applications of nitrogen were also made. The fruit of the treatment at Claremont which included a heavy application of nitrogen had a high concentration of potassium in the juice. This may be associated with the sources of nitrogen which were used, since fruit from the Riverside plot which received high nitrogen has a significantly lower potassium concentration in the juice. The nitrogen for the latter treatment was supplied from calcium nitrate, the calcium of which might be expected to inhibit potassium absorption. The application of manure caused a significant increase in the concentration of potassium in the juice of the fruit at Riverside.

*Calcium in Juice (14):*—At Riverside, the application of potassium in the fertilizer caused a significant decrease in the calcium content of the juice. The application of phosphorus also reduced the calcium. When phosphorus and potassium were applied together, the decrease in calcium content of the juice was highly significant. The application of manure likewise reduced the calcium content, and high nitrogen from calcium nitrate failed to increase the calcium content. At Claremont, these treatments caused no significant differences in the calcium concentration in the juice.

*Effects of Covercrops:*—For the effects of growing a winter covercrop, the means of two sets of four treatments for the Riverside plots (Table III) should be compared. Covercrops apparently had the following effects on the fruit characteristics: (a) a slight, although not significant, decrease in specific gravity of the whole fruit; (b) no

effect on percentage of juice; (c) no effect on the length-width ratio of fruit; (d) a very slight but significant increase in the pH of the juice; (e) a barely significant decrease in the percentage of acid in the juice; (f) a slight decrease in soluble solids; (g) no effect on the ratio of soluble solids to acid; (h) a slight increase in the ascorbic acid; (i) a significant decrease in nitrogen; (j) no effect on the phosphorus; (k) a significant decrease in the potassium; and (1) a significant increase in the calcium content of the juice.

*Correlations:*—It is apparent from the data in Table III, and from the above discussion, that certain characteristics of the fruit from these plots are correlated with the mineral composition of the juice. Simple correlation coefficients are given in Table IV. It was found (a) that a negative correlation existed between the phosphorus content and the acid content of the juice, (b) that a positive correlation existed between the potassium content and the total acid content of the juice, (c) that a positive correlation existed between the phosphorus content of the juice and the percentage of juice of the whole fruit, and (d) that the ascorbic acid content of the juice was negatively correlated with the concentration of phosphorus in the juice. A negative correlation between nitrogen and ascorbic acid in the juice has been previously reported (9, 10).

TABLE IV—Simple Correlation Coefficients Between Certain Fruit Characteristics and Mineral Composition of the Juice of Washington Navel Oranges

| Factors Correlated | Riverside | Claremont |
|---|---|---|
| P and percentage of total acid in juice | −0.304* | −0.471** |
| K and percentage of total acid in juice | +0.674** | +0.674** |
| P and percentage of juice by volume of fruit | +0.447* | +0.505** |
| P and ascorbic acid in juice | −0.210 | −0.613** |

*Significant at 5 per cent.
**Significant at 1 per cent.

## Summary and Conclusions

1. The influence of nitrogen, phosphorus, and potassium fertilizers, and of manure and winter covercrops, on the composition of Washington Navel orange juice in two California orchards is reported.

2. The application of nitrogen fertilizer increased the concentration of nitrogen in the juice. The application of phosphorus likewise increased the concentration of phosphorus, and the application of potassium increased the concentration of potassium in the juice.

3. The growing of winter covercrops reduced the concentration of both nitrogen and potassium in the juice. Covercrops caused a slight increase in the calcium concentration in the juice.

4. The use of manure as the only fertilizer greatly increased the potassium concentration, and reduced the nitrogen and calcium concentrations, in the juice.

5. The following positive correlations were found to be significant: (a) the concentration of potassium in the juice with percentage of

total acid in the juice, and (b) the concentration of phosphorus in the juice with the percentage of juice of the whole fruit.

6. The following negative correlations were found to be significant: (a) the concentration of phosphorus in the juice with percentage of acid in the juice, and (b) the ascorbic acid content with the concentration of phosphorus in the juice.

## Literature Cited


1. Anderssen, F. G. Citrus manuring — its effect on cropping and on the composition and keeping quality of oranges. *Jour. Pomol. and Hort. Sci.* 15: 117–159. 1937.
2. Association of Official Agricultural Chemists. Methods of Analysis. 6th Ed. 932 p. 1945.
3. Batchelor, L. D., Parker, E. R., and McBride, Robert. Studies preliminary to the establishment of a series of fertilizer trials in a bearing citrus grove. *Calif. Agr. Exp. Sta. Bul.* 451. 1928.
4. Chapman, H. D., Brown, S. M., and Liebig, George F., Jr. Big 3 and fruit quality. *Citrus Leaves* 23(8): 11–13, 26–27. 1943.
5. Chapman, H. D., Brown, S. M., and Rayner, D. S. Effects of potash deficiency and excess on orange trees. *Hilgardia* 17: 619–650. 1947.
6. Finch, A. H., and McGeorge, W. T. Fruiting and physiological responses of Marsh grapefruit trees to fertilization. *Ariz. Agr. Exp. Sta. Tech. Bul.* 105. 1945.
7. Forsee, W. T., Jr., and Neller, J. R. Phosphate response in a Valencia grove in the eastern Everglades. *Fla. State Hort. Soc. Proc.* 57: 110–115. 1944.
8. Innes, R. F. Fertilizer experiments on grapefruit in Jamaica. *Trop. Agr. (Trinidad)* 23: 131–133. 1946.
9. Jones, Winston W., and Parker, E. R. Ascorbic acid-nitrogen relations in navel orange juice as affected by fertilizer applications. *Proc. Amer. Soc. Hort. Sci.* 50: 195–198. 1947.
10. Jones, Winston W., Van Horn, C. W., and Finch, Alton H. The influence of nitrogen nutrition of the tree upon the ascorbic acid content and other chemical and physical characteristics of grapefruit. *Ariz. Agr. Exp. Sta. Tech. Bul.* 106. 1945.
11. Parker, E. R., and Batchelor, L. D. Effect of fertilizers on orange yields. *Calif. Agr. Exp. Sta. Bul.* 673. 1942.
12. Peech, Michael, Alexander, L. T., Dean, L. A., and Reed, J. Fielding. Methods of soil analysis for soil-fertility investigations. *U. S. D. A. Cir.* 757. 1947.
13. Sinclair, Walton B., and Bartholomew, E. T. Effects of rootstock and environment on the composition of oranges and grapefruit. *Hilgardia* 16: 125–176. 1944.
14. Sites, J. W. Internal fruit quality as related to production practices. *Citrus Indus.* 29(6): 4, 7–8. 1948.
15. Smith, P. F., Reuther, W., and Gardner, F. E. Phosphate fertilizer trials with oranges in Florida. II. Effects on some fruit qualities. *Proc. Amer. Soc. Hort. Sci.* 53: 85–90. 1949.
16. Takahashi, I. On the effects of potassium upon citrus fruits. *Studia Citrologica* 5(1): 37–54. 1931.
17. ——— The effect of phosphoric acid on citrus. *Okitsu Hort. Soc. Jour.* 27: 18–30. 1931.
18. ——— Effects of phosphoric acid and potassium supplied in summer to orange trees. *Hort. Soc. Japan, Jour.* 6: 54–70. 1935.
19. Young, H. D. Effect of fertilizers on the composition and quality of oranges. *Jour. Agr. Res.* 8: 127–138. 1917.

# Root Distribution in Citrus, as Influenced by Environment[1]

By G. W. ADRIANCE and H. E. HAMPTON, *Texas Agricultural Experiment Station, College Station, Tex.*

As a preliminary study in a comprehensive investigation of factors influencing growth and yield in citrus orchards of the Lower Rio Grande Valley of Texas, a survey was made of the root systems of a large number of trees of Marsh grapefruit. Many problems in orchard soil management have arisen in this area within recent years, and in order to have the proper perspective of these problems, it was considered essential to obtain a thorough knowledge of the root systems of citrus trees growing on the various soils. Soil conditions, as they may have affected present distribution of the roots, were also considered worthy of investigation.

The importance of soil conditions as affecting the distribution of fruit tree roots was emphasized by the work of Oskamp and Batjer (3), who demonstrated that mature Baldwin apple trees in western New York developed entirely different types of root systems on soils of different profiles, and that tree growth and fruit production were closely associated with root distribution. Under such conditions, it was found that certain soils produced profitable orchards, while on other soils, orchards were almost certain to fail.

Ballantyne (1), Yocum (6) and other investigators have found that the roots of apples, peaches and other fruit trees penetrate to considerable depths, in soils of open texture and adequate aeration. Boynton (2) however, has demonstrated that the formation of new roots is dependent upon a greater content of oxygen in the soil than that needed to keep existing roots alive; and also that some soils may be compacted to such an extent that all pore space is taken up by water when the soils are at field capacity.

There is little information available with regard to the root systems of citrus trees. Savage, Piper and Cooper (4) using trees 4 to 6 years old, found that there is considerable difference in the root systems of the various citrus rootstocks, but such differences would be of little significance at the present time in the Lower Rio Grande since the sour or orange stock has been used almost universally. Taylor (5) illustrates the root systems of two Valencia orange trees penetrating to a depth of more than 8 feet, which is considerably deeper than any observed in this study.

In the present investigation, all observations were made on trees of Marsh grapefruit ranging from 10 to 15 years old. All of the trees are on sour orange rootstocks, according to records; but chemical tests to determine identity of rootstocks are being made to eliminate any possible error. In the majority of cases, the observed trees were

[1]The writers wish to acknowledge the invaluable assistance of C. C. Edwards, T. E. Wright, George Otey and George Williams, Soil Technologists employed by Rio Farms, Edcouch, Texas, and San Roman Nursery, Los Fresnos, Texas. Labor for field work was furnished by these companies and much of the supervision was conducted by the men previously mentioned.

in areas where there was apparently some unfavorable condition; but some trees in excellent condition, from the standpoint of growth and fruit production, were included for comparison. Preliminary observation in each case consisted in a careful description of the tree, as to size, general appearance, freedom from disease, and amount of crop.

In the study of the root system, a trench 2 feet wide was opened along the drip of the tree in a line perpendicular to an axis from the trunk outward, as previously described by Oskamp and Batjer (3). Roots taken from the excavation were observed and described but not weighed, because it was soon apparent that different profiles could not be separated as was done by these previous workers. In most cases, it was unnecessary to go below 4 feet to include all of the root zone; a few penetrated to 5 feet while some did not extend below 2 feet.

As soon as it was apparent that no more roots were to be encountered, the inner surface of the excavation next to the tree was marked off into 1-foot squares by means of cotton twine, and the actual distribution of roots as to location and diameter was plotted on graph paper. Further studies were made on trees representative of different conditions of the root system extending back to the trunk and including the tap root. Other observations were made by tracing the lateral extent of roots out to the extremity.

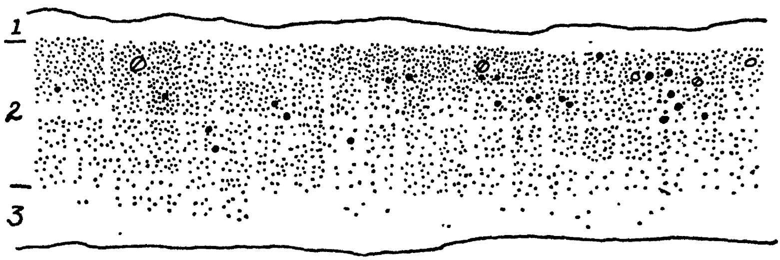
With regard to soil conditions, a number of observations and determinations were made. In the first place, an effort was made to determine the various profiles or strata showing differences in physical appearance and structure. Samples for chemical and physical analysis were taken from these various strata, or at different depths in the excavation, even where no striking physical differences were observed. Rate of water penetration was determined at the various levels by means of percolation tubes of standard diameter and height, which were set up on undisturbed sections of the soil, cut back into shelves.

## Vertical Distribution of Roots

During the period of 1942 to 1946, a total of 93 trees have been excavated and studied as described above. A few typical cases will be discussed briefly, to indicate several commonly occurring situations.

*Tree No. 1:*—Approximately 15 years old, but only 6 to 7 feet tall with about the same spread of branches. Much dead wood, little new growth, and practically no fruit. Soil from surface level down to 24 inches black and very compact, of type known as "hog wallow". Few roots ranging from ½ to 1 inch in diameter in upper 8 inches, and numerous small, fibrous roots down to 24 inches. No roots below this level. Soil below 24 inches very dense, compact clay, not excavated below 30 inches. Entirely unsuited to fruit trees and orchard subsequently removed (Fig. 1).

*Tree No. 2:*—Medium sized tree, 14 feet tall and 16 feet spread, foliage somewhat pale, little new growth, some dead wood throughout whole tree, approximately 1 box of fruit on tree. Soil from surface to 23 inches in depth grayish brown fine sandy loam, rather compact,




1. 3/4" Plowed surface composed of dark gray finely cloddy clay, very plastic when wet.

2. 22" Dark gray, tight, very dense clay, very slowly permeable, deep cracks form on drying.

3. Light brown crumbly moderately permeable clay.

FIG. 1. Vertical distribution of roots of Marsh grapefruit tree on heavy, compact soil (Tree No. 1). Location B. V. 5.

but with roots of small size and up to 1 inch diameter well distributed. Below 23 inches, soil gray and compact, sandy clay, rather moist, very few roots present, becoming increasingly gray in color, and with higher moisture content, with caliche at 48 to 50 inches, and water table only a few inches lower at about 5 feet (Fig. 2).

*Tree No. 3:*—Large, healthy tree, 18 feet high, 22 feet spread, branches meeting others in row, good crop of fruit on tree, and general


1. 0-8" Medium gray sandy clay loam, compact brittle when dry.

2. 8-23" Brownish-gray clay loam, crumbly and friable.

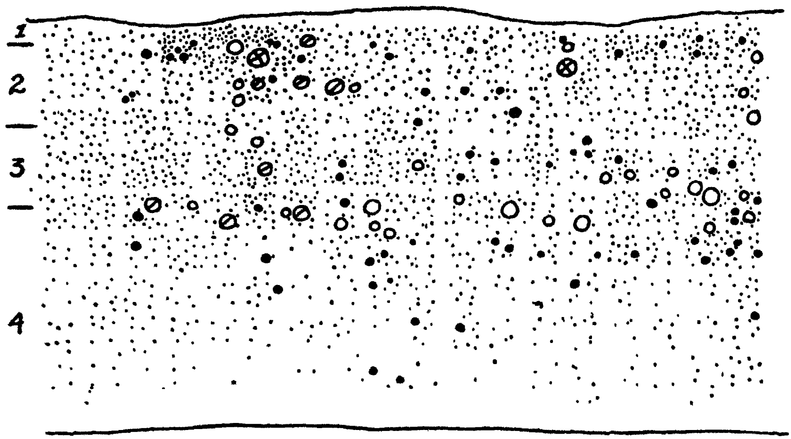
3. 23-39" Light brownish-gray crumbly clay to clay (increasing clay with depth), few lime concretions, layer saturated with water.

4. 39-46" Light gray clay, plastic but rather crumbly, containing numerous lime concretions, saturated with water.

Free water surface at 51 inches.

FIG. 2. Vertical distribution of roots of Marsh grapefruit tree on compact gray sandy soil (Tree No. 2). Location 15 A-R F.

appearance very satisfactory. Soil from surface to 24 inches in depth brown sandy loam, good condition and texture, and with excellent distribution of roots. Below 24 inches and down to 60 inches, soil is of similar color and texture, becoming only slightly lighter in color and slightly more compact, but of the same general physical composition. Some shell in all levels of the soil, and with more in the lower levels, and no impervious layers. Roots continuing down to 60 inches in good distribution and some roots below this level. Appears to be an ideal orchard soil (Fig. 3).




1. 0-4" Dark greyish-brown crumbly clay loam.
2. 4-16" Grayish-brown rather compact calcareous clay loam containing numerous snail shell fragments, moderately permeable.
3. 16-27" Light brownish-gray calcareous permeable silty clay loam.
4. 27-62" Very light brownish-gray calcareous permeable silt loam.

No water table encountered.

FIG. 3. Vertical distribution of roots of Marsh grapefruit tree on deep soil of good texture (Tree No. 3). Location B. V. 51.

The patterns of root distribution described above are representative of these found in different orchards of the Rio Grande Valley. Factors which appear to be responsible for these conditions are: (a) heavy clay soil or dispersed layers near the surface that retard water penetration and root growth; (b) densely compacted areas at 24 to 36 inches and below which have the same effect; (c) poor drainage, with water table at 48 to 60 inches, and with wet soil 12 to 24 inches above the water table; (d) increasing concentration of soluble salts in lower levels of soil, which is probably associated with high water table; (e) soils in good physical condition, with no impervious layers in the first 60 inches and probably as good in lower levels.

Soil conditions as described under Tree 1 represent the extreme of

an unsatisfactory location for an orchard. Some such soils have been set to trees in past years, but most of these trees have failed and have been removed. Tree 3 represents a most desirable soil condition and trees planted on such soils have excellent chance for success particularly if fertility levels are maintained. Unfortunately, however, many orchards are at the present time in the condition described for Tree 2, and the soil in most cases presents somewhat the same condition as found in this particular tree. It is with orchards in this condition, and others that may be expected to approach it soon, that corrective treatments, in various methods of soil management, may be most effective.

## Lateral Distribution of Roots

A number of trees under different systems of soil management were observed, and two extreme cases are cited for comparison.

*Tree No. 4:*—Medium sized tree, 10 feet high, and 12 feet spread, fair crop of fruit. Root system densely branched at spread of tree and under the tree, almost up to the trunk. Orchard under clean cultivation and irrigated by basin method. Borders put up with double-disk machine that cuts to depth of 10 inches, and apparently restricts the outward spread of roots (Fig. 4).

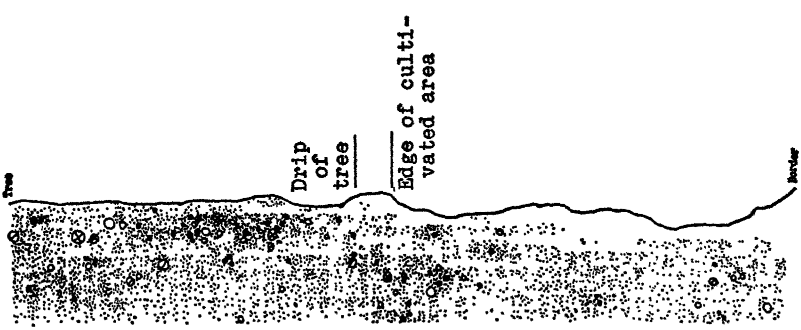



Fig. 4. Root system of Marsh grapefruit tree, showing lateral extent of roots in a cultivated and bordered orchard. Location 10 A-R F.

*Tree No. 5:*—Small tree, 10 feet high, and 10 feet spread, rather poor condition, light crop of fruit. Roots extend out from tree, one or two to distance of 18 to 20 feet, where they cross roots from other trees. Orchard in mixed sod, as a result of non-cultivation, and trees in poor condition, due to lack of care over a period of years. Lateral extent of roots might be induced to same extent through the use of a permanent cover, cut at regular intervals (Fig. 5).

Cultural practices as outlined for Tree 4 represent one probable cause of the failure of citrus roots to penetrate the area between the trees, where water and nutrients are most easily applied. Another possible cause of the restricted root distribution in this area is brought out by Taylor (5) who showed the effect of compaction of this middle area by cultivation equipment.

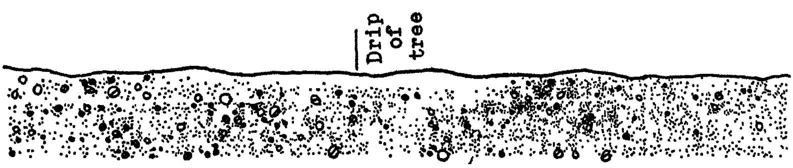



FIG. 5. Root system of Marsh grapefruit tree showing lateral extent of roots in an uncultivated orchard. Location 11 A-R F.

Conditions found and described under lateral and vertical distribution of roots indicate the need for extensive studies in subsoil drainage, irrigation and leaching studies, cover crops and other aspects of soil management, and the use of soil amendments to modify physical conditions. Work along several of these lines is under way, at the present, and other work will be initiated at an early date.

## LITERATURE CITED


1. BALLANTYNE, A. B. Fruit tree root systems spread and depth. *Utah Agr. Exp. Sta. Bul.* 143. 1916.
2. BOYNTON, DAMON. Soil atmosphere and production of new rootlets by apple tree root systems. *Proc. Amer. Soc. Hort. Sci.* 37:19–26. 1939.
3. OSKAMP, JOSEPH, and BATJER, L. P. Size, production, and rooting habit of apple trees on different soil types in the Hilton and Morton areas, Monroe County. *Cornell Univ. Agr. Exp. Sta. Bul.* 550. 1932.
4. SAVAGE, E. M., COOPER, WILLIAM C., and PIPER, R. B. Root systems of various citrus rootstocks. *Proc. Fla. State Hort. Soc.* 44–48. 1945.
5. TAYLOR, C. A. Irrigation problems in citrus orchards. *U. S. D. A. Farmers' Bul.* 1876. 1941.
6. YOCUM, W. W. Root development of young Delicious apple trees as affected by soils and by cultural treatments. *Neb. Agr. Exp. Sta. Res. Bul.* 95. 1937.

# Relation of Fertilizers to Cold Injury to Tung Trees Occurring at Lucedale, Mississippi, in March 1948

By Ralph T. Brown, *U. S. Department of Agriculture, Spring Hill, Ala.,* and George F. Potter, *U. S. Department of Agriculture, Bogalusa, La.*

On March 13, 1948, unseasonably low temperatures occurred in tung orchards in the vicinity of Lucedale, Mississippi.[1] Fernholz and Potter (3) have shown that the tissues of the tung tree have a wide range in cold resistance; when fully dormant the tree can withstand temperatures close to 0 degrees F, but when in active growth it is exceptionally sensitive to cold. The low temperatures at Lucedale, Mississippi, occurred at a rather sensitive stage, just after flower buds were commencing to expand, and considerable injury to blossoms and trees occurred. In one of the orchards in this vicinity, a factorial experiment with three levels each of nitrogen, phosphorus, and potassium had been in progress since 1940.[2] Soon after the low temperatures occurred, it was noted that the fertilizers had had a very striking effect upon resistance of the trees to cold. An exceptional opportunity was thus afforded to study the effect of the fertilizers on cold resistance of the tung tree under field conditions.

The treatments used in this experiment have been described in detail by Bahrt and Potter (1). In brief they were as follows: for the period 1941 to 1946 inclusive, the low level of nitrogen was that supplied by the soil and cover crops or native legumes. At the intermediate and high levels, supplementary applications of 0.25 and 0.50 pound of N per tree, respectively, were made in the form of sodium nitrate, ammonium sulfate, or ammonium nitrate. The low level of phosphorus consisted of an application of 40 pounds of $P_2O_5$ per acre, broadcast in June on a cover crop or the native vegetation. At the intermediate and high levels of phosphorus, supplementary applications of superphosphate were made, carrying 0.25 and 0.50 pound of $P_2O_5$ per tree, respectively. The low level of potassium was that available from the soil and at the intermediate and high levels, muriate of potash was applied in amounts carrying 0.19 and 0.38 pound of $K_2O$ per tree, respectively. In 1947 the supplementary applications of nitrogen, phosphorus and potassium at the intermediate and high levels of each were increased 50 per cent. The 27 treatments, resulting from all possible combinations of the three levels of each nutrient, were set up in plots of six trees each, with four replications. The trees which were 14 years old in March 1948, are planted in squares 25 feet apart each way, on a Red Bay fine sandy loam soil.

It is generally recognized that heavy crop production and factors

[1]No accurate readings of the low temperatures are available. The official minimum temperature at Mobile, Alabama, was 31 degrees F, but it is believed that temperatures of 28 degrees F or lower occurred in the orchards.

[2]This experiment was set up by the late George M. Bahrt, associate soil technologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, and was conducted by him until his death in April 1947.

that reduce the foliage or impair its efficiency lower the resistance of fruit and nut trees to cold. Routine records of production, relative maturity of the crop, amount of shoot growth and foliage disorders, which had been taken during the season of 1947, are therefore of interest in this connection. A statistical analysis of yield records showed that, as reported for previous seasons by Bahrt and Potter (1), yields were affected only by the nitrogen; the weights of air-dry fruit per tree produced at the low, intermediate, and high levels of nitrogen were, respectively, 17.2, 29.7, and 35.7 pounds, supported by an observed value of F of 35.51, where 7.76 is required at the .001 level of probability. Tung fruits are allowed to mature on the trees and drop to the ground. On October 8, 1947, the trees in the experiments were rated with respect to maturity of the crop on a scale ranging from 1.00, representing a tree from which no fruit had dropped, to 5.00, representing a tree from which three-quarters to all of the fruits were on the ground. Each tree was rated individually, an average rating per plot was calculated, and the plot readings were analyzed statistically. It was found that increasing the potassium tended to cause early maturity of the crop, the average ratings for the low, intermediate, and high levels of potassium being, respectively, 2.58, 2.88, and 3.22. These readings are supported by a value of F of 9.49, where 7.76 is required for statistical significance at the .001 level. Increasing the nitrogen tended to delay maturity, but the effect was less consistent and less marked. The average readings for the low, intermediate, and high levels of nitrogen were, respectively, 2.94, 3.06, and 2.68, supported by a value of F of 3.64, which indicates statistical significance approximately at the .05 level. Other things being equal, early maturity of the crop would tend to increase true cold resistance, since the trees would have some time before leaf-fall to rebuild the reserves of both minerals and elaborated food materials removed by the fruits produced.

It would be expected that cold injury occurring in the fall, winter, or early spring, would be inversely proportional to the amount of healthy foliage carried the previous season by the trees. It was not feasible to make estimates of leaf area but in general the amount of foliage would be proportional to the shoot growth. Normally in tung all of the new shoots arise from the terminal buds of the previous season. The total 1947 shoot growth, arising from eight terminal buds of the 1946 season, taken at random from representative areas on four sides of each tree, was measured. The readings for each plot were averaged and expressed as number of centimeters of shoot growth per terminal bud of the previous season. It was found that both nitrogen and potassium had tended to increase the shoot growth and hence the leaf area. The readings for the low, intermediate, and high levels of nitrogen were, respectively, 11.0, 22.3, and 28.3 centimeters; for the low, intermediate, and high levels of potassium they were 16.9, 21.4, and 23.3. The effect of nitrogen is supported by a value of F of 53.7, and that of potassium by a value of 7.61, where 7.76 is required for statistical significance at the .001 level.

Inasmuch as the application of nitrogen tended to increase the crop, which would tend to lower the cold resistance, and to increase the

shoot growth and hence the foliage, which would have the opposite effect, it was thought worth while to determine the ratio of shoot growth to fruits produced. Tung bears on the terminal shoots of the previous season and the fruit stems persist for several years. Thus it was possible, when taking the terminal growth measurements, to record the number of fruits borne on each terminal and to compute the number of centimeters of shoot growth for each fruit borne.[3] It was found that the increase in 1947 shoot growth effected by the nitrogen was greater proportionately than the increase in the crop. Thus the total 1947 shoot growth per fruit borne the same year was 18.4, 26.3, and 30.2 centimeters, respectively, for the low, intermediate, and high levels of nitrogen. The effect of the nitrogen is supported by an F value of 12.00, where 7.76 is required at the .001 level. A similar trend existed for the potassium the low, intermediate, and high levels of which the readings were 23.2, 25.9, and 26.9 cms respectively; but these differences are too small to attain statistical significance.

During the fall of 1947 a scorch of the foliage was observed, which has been described by Drosdoff and Painter (2) and ascribed to potassium deficiency. The trees were scored for incidence of this disorder on a scale ranging from 1.00 for normal foliage, to 5.00 for trees on which 76 to 100 per cent of the leaves showed the disorder. An analysis of these readings showed that the incidence of scorch was markedly reduced by the application of potassium, the average ratings for the low, intermediate, and high levels of potassium being, respectively, 2.43, 1.78, and 1.66. It has been rather consistently noted in experiments with tung at other locations, as pointed out by Sitton, Painter and Brown (5) that nitrogen tends to increase the scorch due to potassium deficiency. In this experiment a similar trend was observed, the average ratings for the low, intermediate, and high levels of nitrogen being 1.73, 2.01, and 2.12 respectively. Although these differences are too small to attain statistical significance even at the .05 level, under the conditions of the Lucedale experiment, in view of experience elsewhere it may be assumed that the nitrogen tended to increase the scorch especially at the low levels of potassium. Scorch of the foliage must reduce its photosynthetic efficiency and tend to lower cold resistance.

During the summer of 1948 it became apparent that the extent of the cold injury suffered by the tung trees had been influenced profoundly by the fertilizer treatment. The extent of the injury was estimated on a scale ranging from 1.00 for a tree that was uninjured, to 5.00 for a tree that had been completely killed. An individual rating was made for each tree and averages were calculated for each plot. The data show that increase both of nitrogen and of potassium significantly reduced the injury. The over-all average injury ratings for the low, intermediate, and high levels of nitrogen were, respectively, 1.94, 1.65, and 1.48, while those for the corresponding levels of potassium were 1.99, 1.62, and 1.45. The observed values of F, 10.09 for the nitrogen and 14.34 for the potassium, are higher than required for

[3]These data were examined by the Bartlett chi-square test and found suitable for the conventional analysis of variance.

statistical significance at the .001 level. Furthermore there was a very striking interaction between nitrogen and potassium (Table I). At the low level of potassium, nitrogen failed to improve the cold resistance of the trees and it was most effective at the intermediate and high levels of potassium. Conversely potassium was most effective in reducing the cold injury when applied in conjunction with the intermediate and high levels of nitrogen.

TABLE I—EFFECTS OF NITROGEN AND POTASSIUM ON RATINGS* FOR COLD INJURY SUSTAINED BY TUNG TREES (LUCEDALE—MARCH 1948)

| Level of Nitrogen | Level of Potassium | | |
|---|---|---|---|
| | Low | Intermediate | High |
| Low | 1.91 | 2.02 | 1.88 |
| Intermediate | 2.01 | 1.56 | 1.36 |
| High | 2.04 | 1.29 | 1.10 |

Least difference significant at .05, 0.36; at .01, 0.48; at .001, 0.62. F for N.K. interaction: observed, 4.23; required at .01, 3.56; at .001, 5.31.

*On scale ranging from 1 00 for uninjured tree, to 5.00 for tree completely killed.

The data show that those trees that had received the high levels of both nitrogen and potassium had suffered little loss of bearing surface, the average rating being 1.10, where 1.00 would indicate no killing of twigs or branches (Table I). In addition there had been very little damage to the blossom buds, such that they appeared to be carrying practically a full crop. The number of fruits per terminal was counted on eight terminals per tree, taken at random from representative areas on four sides of each tree. As before, the average number of fruits per terminal was calculated for each of the 108 plots and an analysis of the data shows that the nitrogen had an outstanding effect on survival of the blossom buds. In 1948, following the cold weather, the trees at the low level of nitrogen had an average of only .079 fruits per terminal, those at the intermediate level .434, and those at the high level .896, supported by an observed value of F of 67.61, where 7.76 is required at the .001 level. Potassium also tended to improve the survival of the blossom buds, the average number of fruits per terminal in 1948 being .360, .478, and .570, respectively, at the low, intermediate, and high levels of potassium. These differences attain statistical significance at approximately the .01 level.

As in the case of injury to the twigs and branches, number of fruits per terminal showed a significant interaction between nitrogen and potassium; by far the best set of fruit was attained where high levels of both nitrogen and potassium were used (Table II). Where both levels were high the average number of fruits per terminal was 1.122, as compared with an average of 1.032 fruits per terminal for the same trees in 1947 when no frost occurred.

It is believed that susceptibility to cold injury is the resultant of several interacting factors. Thus, as has previously been pointed out, greatest cold resistance would be expected in trees bearing small crops that matured early and carrying large amounts of healthy foliage the previous season. The applications of nitrogen tended to increase yields, and the incidence of scorch, but to greatly increase the shoot growth

TABLE II—EFFECTS OF NITROGEN AND POTASSIUM ON NUMBER OF FRUITS SET PER LIVING TERMINAL FOLLOWING COLD INJURY TO TUNG TREES AT LUCEDALE, MISSISSIPPI (MARCH 1948)

| Level of Nitrogen | Level of Potassium | | |
|---|---|---|---|
| | Low | Intermediate | High |
| Low . . . . . | 0.080 | 0.071 | 0.065 |
| Intermediate . . . . . | 0.419 | 0.379 | 0.504 |
| High . . . . . | 0.583 | 0.983 | 1.122 |

Least difference significant at .05, .244; at .01, .325; at .001, .422. F for N.K. interaction: observed, 3.31; required at .05, 2.48; at .01, 3.56.

and hence the amount of foliage. The nitrogen had an outstanding effect on survival of flowers, possibly because it delays opening of the buds. Although no data are included here, the senior author has demonstrated that nitrogen delayed bloom in tung orchards at Monticello, Florida, and unpublished observations by Bahrt in the Lucedale orchard support this conclusion. Potassium tended to accelerate the maturing and dropping of the fruit, to increase the amount of foliage, and to keep it healthy. In addition, as Cooper et al (4) have pointed out, it tends to increase photosynthetic activity.

The set of fruits on the low levels of nitrogen and potassium represented a crop loss due to cold injury of 75 to 80 per cent. On the other hand the trees receiving high levels of both nitrogen and potassium bore a full crop. These findings are of much significance to the tung industry. A late freeze might sometimes occur that would destroy the crop regardless of treatment, but it is evident that the cold hazard can be greatly reduced by adequate fertilization.

## SUMMARY

In a tung orchard at Lucedale, Mississippi, trees that had received liberal applications of nitrogen and potassium over a period of 7 years, suffered practically no loss of bearing surface in a late freeze on March 13, 1948, and set a full crop. The average loss of bearing surface on unfertilized trees, many of which were killed outright, was severe, and the crop was reduced by 75 to 80 per cent. Data on yield, date of dropping of the mature fruit, shoot growth, and foliage disorders that have a bearing on cold resistance, are presented and discussed.

## LITERATURE CITED

1. BAHRT, G. M., and POTTER, G. F. Effect of nitrogen, phosphorus, and potassium on growth and yield of tung trees and composition of fruits. *Proc. Amer. Soc. Hort. Sci.* 50: 137–141. 1947.
2. DROSDOFF, MATTHEW, and PAINTER, J. H. A chlorosis and necrosis of tung leaves associated with low potassium content. *Proc. Amer. Soc. Hort. Sci.* 41: 45–51. 1942.
3. FERNHOLZ, D. L., and POTTER, G. F. Preliminary experiments on the resistance of the tung tree to low temperature. *Proc. Amer. Soc. Hort. Sci.* 39: 167–172. 1941.
4. COOPER, H. P., SCHREINER, OSWALD, and BROWN, B. E. Soil potassium in relation to soil fertility. *Yearbook of Agriculture,* pp. 401–402. 1938.
5. SITTON, B. G., PAINTER, J. H., and BROWN, R. T. Increasing profits from tung orchards with potassium. *Proc. Fourteenth Ann. Conv. Amer. Tung Oil Assn,* pp. 16–20. 1948.

# Observations on Cold Injury to Tung Trees in Louisiana and Texas, Occurring in Late March 1948

By GEORGE F. POTTER, *U. S. Department of Agriculture, Bogalusa, La.*

THOSE areas in the southeastern United States where tung is extensively planted on a commercial scale lie for the most part within 50 to 75 miles of the Gulf of Mexico. However, considerable interest has been shown in extending the northern limits of commercial tung growing and experimental plantings have been made in north central Georgia, north central Mississippi, northern Louisiana, and eastern Texas. In common with other parts of the continental United States, exceptionally cold weather prevailed in the tung areas during January and February 1948 (Table I). However, in late February and early March the weather was unseasonably warm (Table II). Since the rest period of the tung trees had been completely broken by the cold winter weather, they tended to respond to the favorable growing conditions. Subsequently a severe cold wave occurred in March.

TABLE I—OFFICIAL MONTHLY MINIMUM TEMPERATURES (JANUARY TO MARCH 1948) AT STATIONS IN LOUISIANA AND TEXAS, REPRESENTATIVE OF TUNG GROWING AREAS

| Station | County or Parish | State | Minimum Temperatures | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | January | | February | | March | |
| | | | Degrees F | Date | Degrees F | Date | Degrees F | Date |
| Calhoun...... | Ouachita | Louisiana | 9 | 8 | 21 | 1 | 21 | 13 |
| Pollock....... | Grant | Louisiana | 2 | 24 | 20 | 1 | 20 | 13 |
| Colfax....... | Grant | Louisiana | 5 | 24 | 25 | 1 | 25 | 13 |
| De Ridder.. . | Beauregard | Louisiana | — | — | 27 | 14 | 26 | 12 |
| Franklinton... | Washington | Louisiana | 12 | 24 | 22 | 1 | 26 | 13 |
| Covington.... | St. Tammany | Louisiana | 15 | 24 | 25 | 1 | 30 | 13 |
| Nacogdoches* | Nacogdoches | Texas | 15 | 24 | 25 | 14 | 18 | 12 |
| Kirbyville*... | Jasper | Texas | — | — | 25 | 1 | 24 | 12 |

*No weather station in Tyler or Hardin Counties, Texas, where observations were made. Readings from Nacogdoches and Kirbyville are the nearest available.

TABLE II—DAILY MINIMUM AND MAXIMUM TEMPERATURES (POLLOCK, LOUISIANA, FEBRUARY 26 TO MARCH 3, 1948)

| | Minimum Degrees F | Maximum Degrees F |
|---|---|---|
| February 26........ | 59 | 72 |
| 27........ | 62 | 76 |
| 28........ | 53 | 72 |
| 29........ | 48 | 83 |
| March 1........ | 53 | 73 |
| 2........ | 54 | 80 |
| 3........ | 47 | 80 |

Fernholz and Potter (1) have shown by artificial freezing tests, that twigs and branches of the tung tree are very resistant to cold injury when fully dormant, but become very sensitive to cold when active growth starts. Experience in the orchard has confirmed these findings. The trees have not been injured by midwinter temperatures

close to 0 degrees F, but at Citronelle, Alabama, and Richton, Mississippi, temperatures of 23 to 25 degrees F occurring on March 3-4, 1943, after the buds had begun to swell, not only destroyed the crop but also killed many trees and caused severe losses of bearing wood in trees that survived.

During March 1948 there seemed to be little difference in stage of development between tung trees in the commercial districts of Louisiana and southwestern Mississippi and those in the westerly and northerly experimental plantings. As the cold fronts advanced southward and eastward, they tended to moderate and little injury occurred in the commercial tung districts.[1] At Franklinton and Covington, Louisiana, minima of 26 degrees F and 30 degrees F were observed on March 13 (Table I) and practically no injury either to wood or blossom buds occurred. At De Ridder, Louisiana, where 26 degrees F was registered, no twig or branch killing occurred, and with but slight injury to the blossom buds nearly a full crop was set. However, in northern Louisiana and eastern Texas the temperatures that occurred in March were just enough lower than those that occurred farther south and east to cause considerable injury to trees and blossoms (Table I). Observations in the plantings in Louisiana and Texas have brought out some facts that seem worth reporting. The points at which observations mentioned in this paper were made or at which weather records were taken are shown in Fig. 1.


FIG. 1. Points at which observations on injury to tung trees were made, or weather records were obtained.

[1]Injury occurred at Lucedale and other points along the northern border of the tung districts from central to eastern Mississippi. It was apparently due to the trees being in an advanced stage of growth rather than to exceptionally low temperatures.

## Age of Tree

Age appears to have been an important factor. About a dozen tung trees were planted at the North Louisiana Experiment Station at Calhoun, Louisiana, in 1930. They have suffered very little cold injury, having withstood a temperature of 3 degrees F in February 1940 and having produced a crop every year from 1934 through 1947. The 1948 March freeze caused no twig or branch injury to these mature trees, but the blossom buds were almost completely destroyed. On the other hand, some 5-year-old trees in a variety test orchard about a mile from the Experiment Station, under comparable conditions as to soil and culture, suffered rather severe injury to the wood (see Fig. 2). Scored on a scale ranging from 1.00 for trees showing no injury to the twigs or branches, to 5.00 for a tree completely killed, the average rating for injury to the young trees was 2.47. The old trees are of miscellaneous seedling origin, while the young trees comprised 25 different budded varieties or seedling progenies. Presumably the 25 sorts would differ a little on the average from the old trees and, if any different, would be expected to have greater inherent cold resistance (see below).

Young trees near Pollock and Colfax, Grant Parish, central Louisi-

Fig. 2. Five-year-old tung trees at Calhoun, Louisiana, severely injured by late freeze, March 13, 1948. Note terminal buds expanded. Mature trees under comparable conditions suffered no injury to twigs and branches.

ana, were killed back even more severely than those at Calhoun. A considerable number of farmers in Grant Parish had made rather extensive plantings, a large proportion of which were seedlings from a selection known as the McKee. On the basis of previous experience and of observations made this season, McKee seedlings are considered somewhat tender to cold. Very serious damage occurred to these trees, which were from 1 to 3 years old. Most of them were killed back almost to the ground level and in June of 1948 were starting out from adventitious buds on the trunks and larger branches. The few old trees in Grant Parish were similar to those at Calhoun, practically uninjured in the wood but bearing no crop.

## Culture and Fertilization

None of the plantings observed in Louisiana and Mississippi were in formal fertilizer experiments, but there were clearcut correlations between extent of injury and the care that the trees had received. Thus at Woodville, Tyler County, Texas, an orchard of 12- to 14-year-old trees on satisfactory soil but unfertilized and practically uncultivated, suffered seriously. About 25 per cent of the trees were dead, most of the others lost large branches and sometimes all the main branches were killed back. Some 3 miles distant there is a test orchard comprising practically the same varieties as those at Calhoun, Louisiana. These 5-year-old trees had been cultivated four times during the season of 1947 and had received a liberal application of fertilizer. There was scarcely a dead branch to be seen and many of these young trees were bearing a considerable number of fruits (Fig. 3).

## Variety

Injury of varying degrees occurred in two variety trials, the one at Calhoun, Louisiana, planted in 1943, and one at Silsbee, Texas, planted in 1941. Each tree in these experiments was scored on the scale previously described. There was much variation between individuals within a variety. Apparently the stage of development was an extremely important factor and within any given clone there is always some variation among individual trees in stage of development of the buds. These slight differences in stage of development or degree of growth activity between the trees of a given clone may account for varying degrees of injury observed. In spite of the variation within clones, a statistical analysis of the data showed that at both locations variety differences attained statistical significance at the .01 level. The trees at Silsbee, Texas, planted in 1941, were propagated from selections made in 1938 when little or no evidence was available as to relative hardiness of the parent trees. Those planted at Calhoun in 1943 were propagated from trees selected following the cold winter of 1939–40 and the very severe fall freeze that occurred in November 1940. At Calhoun the varieties that suffered the least injury were the M–22, F–555, M–1, L–51–s, G–46, and L–56–s, with average injury ratings ranging from 1.62 to 1.85. Within this range no distinctions can be drawn, but there can be no doubt that the varieties listed are more cold resistant than, for example, G–38, which scored 3.50, L–

FIG. 3. Five-year-old tung trees under good culture at Woodville, Texas, were uninjured, whereas older trees in neglected orchards were killed or seriously injured.

126, a McKee selection, which scored 3.40, and F–9, which scored 3.35.

At Silsbee the clones L–14, L–2, L–9, L–22, F–508, F–541, and M–1 were most resistant. Of those found most resistant at Silsbee, only the L–14 is represented at Calhoun. The average injury rating for L–14 at Calhoun was 2.68, 0.98 greater than the injury to the M–1, where the least difference significant at .05 is 1.14. Although the L–14 has generally been considered rather susceptible to cold injury, it withstood the March freeze well, not only at Silsbee but also at Meridian, Mississippi, and at Experiment, Georgia.[2]

## SUMMARY

The tung trees in northerly experimental plantings were subjected to a rigorous test in the March 1948 freeze. The evidence indicates that the more cold resistant varieties, if well cared for, can be planted without undue risk in northern Louisiana and eastern Texas. It may be expected that risk of loss will diminish as the trees grow older.

## LITERATURE CITED

1. FERNHOLZ, D. L., and POTTER, G. F. Preliminary experiments on the resistance of the tung trees to low temperature. *Proc. Amer. Soc. Hort. Sci.* 39: 167–172. 1941.

[2]Observations at Meridian, Mississippi, were made by A. C. Gossard; those at Experiment, Georgia, were made cooperatively with F. F. Cowart.

# The Effects of Different Methods of Girdling Bearing and Defruited Tung Branches[1]

By BENJAMIN G. SITTON, *U. S. Department of Agriculture, Bogalusa, La.*

GIRDLING of branches of fruit trees has frequently been found to be a very useful technique in studies of the relation of leaf area to the formation of fruit buds and the set and development of the fruit. Early attempts to use this technique with tung trees were discouraging because many of the girdled branches died. Painter and Brown (1) studied the effect of the time and of different methods of girdling tung branches and reported that the leaves above the girdle became thickened and yellowish, which indicated an accumulation of carbohydrates. They also reported swelling of the stem above the girdle, which they concluded was the best criterion of the effectiveness of the girdle. On this basis, the most effective treatment used was removal of a ring of bark without covering the wound; the least effective was binding the stem with wire. When only a single knife cut was made the wounds healed well, but wounds made by the removal of a ring of bark failed to heal unless waxed. No reports was made on the survival of the branches or the effect of the girdle on pistillate flower differentiation.

## METHODS

To obtain further information on the effect of different methods of girdling, including survival of the branches and pistillate flower differentiation, an experiment was initiated in May 1944 in which 5-year-old tung trees of the clone M–1 were used. The experiment was set up in factorial design with five pairs of opposing factors: (a) date, May 15 versus August 17; (b) crop, non-bearing versus at least one fruit per terminal; (c) method, a closed ring around the stem versus a helix of approximately one and one-half turns around the stem made at such an angle with the stem axis that the basal and distal portions were separated by a strip of uninjured bark approximately equal in width to the diameter of the stem; (d) severity, double knife cuts $^{3}/_{16}$ inch apart through the bark to the wood versus similar cuts with the bark between removed; and (e) protection, none versus covered with waxed cloth or electricians' tape.

Five replications were set up, each plot being a single branch with several fruiting terminals, and eight branches on a single tree constituting a block. This permitted the use of a design involving balanced partial confounding, in which a different group of interactions, two second-order and one third-order, were confounded with the blocks in each replication (Yates 4). Since in the factorial experiment every branch was girdled in one manner or another, an ungirdled fruiting branch was selected on each tree to serve as a check. The blocks and treatments were assigned at random.

[1]The writer wishes to thank Dr. George F. Potter, principal physiologist, Division of Fruit and Vegetable Crops and Diseases, for his valuable suggestions in the conduct of this study and in preparation of the manuscript.

All girdles were made on the 2-year-old wood. Two complete experiments were set up; in one electrician's tape was used as a wound covering, and in the other cloth impregnated with wax composed of four parts rosin and two parts beeswax. No differences ascribable to the type of tape were observed and therefore the data for the two kinds have been combined. Extra treatments were set up to be used in microscopic studies of the wound reaction if that seemed desirable.

Twenty-five branches broke off at the girdle before the end of the 1944 growing season and 15 others either broke off or the branch beyond the girdle died prior to the final observation. Data on fruit set from extra treatments originally intended for microscopic study and which had had the same treatment as the missing branches, were substituted in the analysis of the effect of the treatments. It is believed that data from these are better than values substituted by means of a statistical missing plot technique.

Observations were made at irregular intervals during the growing season of 1944. Swelling of the stems above the ring as reported by Painter and Brown (1) was observed in early summer on treatments made in May, but yellowing and wilting of the leaves was not observed until early September. Some of the girdled branches had lost many leaves by November 10, at which time the leaves on the check branches were still green.

The effects of the treatments upon the healing of the wounds, the vigor of the new shoots, and the set of fruits per terminal were recorded May 9, 1945; and the final record of the effect upon the healing of the wounds, swelling of the stem, and the survival of the treated branches was made October 22, 1946.

## Results

*Healing of Wounds:*—The healing of the wounds was estimated and recorded by use of a rating scale ranging from 1.00 for no apparent healing to 4.00 for apparently perfect healing. Of the five pairs of factors, the severity of the wound resulted in the greatest differences in the healing of the wounds (Table I). Wounds made by scoring only had almost completely healed by the following spring, while wounds from which the strip of bark between the knife kerfs was removed were less than three-quarters healed. In October 1946, nearly two years after the wounds were made, some of the latter class of wounds still were not completely healed, as is indicated by the average rating of 3.36 (Table I).

Protection of the wounds from desiccation by covering with tape was effective in promoting healing of the wounds. Wounds made in May 1944 had healed to a greater extent by the following May than had wounds made in August 1944; but by October 1946 there was no significant difference. Girdles made in helical form tended to heal better than those made as a closed ring, and wounds on defruited branches tended to heal faster than those on bearing branches; but in the latter comparison differences were less than required for significance at the .05 level. It would seem from the foregoing data that wounds made in May by scoring only and protected from desiccation

TABLE I—THE EFFECTS OF GIRDLING TUNG BRANCHES MAY 15 TO 18 AND AUGUST 17 TO 21, 1944, UPON THE HEALING OF THE WOUNDS, VIGOR OF NEW SHOOTS, SWELLING ABOVE THE WOUND, SURVIVAL OF BRANCHES, AND THE NUMBER OF FRUIT SET

| Treatment | Healing of Wounds May 1945 (Rating)* | Healing of Wounds Oct 1946 (Rating)* | Vigor of New Shoots May 1945 (Rating)** | Swelling Above Girdle Oct 1946 (Rating)† | Branches Failing to Survive Oct 1946 (Per Cent) | No. Fruit Per Terminal Bud May 1945 |
|---|---|---|---|---|---|---|
| Branches defruited | 3.29 | 3.68 | 3.26 | 2.04 | 10.0 | 1.30 |
| Branches bearing | 3.19 | 3.52 | 3.17 | 2.05 | 15.0 | 1.15 |
| Ring girdle | 3.18 | 3.40 | 3.08 | 2.22 | 18.8 | 1.23 |
| Helical girdle | 3.31 | 3.79 | 3.35 | 1.87 | 6.2 | 1.22 |
| Scored only | 3.74 | 3.83 | 3.48 | 1.48 | 6.9 | 1.24 |
| Bark removed from girdle | 2.74 | 3.36 | 2.95 | 2.61 | 18.1 | 1.21 |
| Wound unprotected | 2.99 | 3.50 | 3.11 | 2.01 | 18.1 | 1.25 |
| Wound protected | 3.49 | 3.69 | 3.32 | 2.08 | 6.9 | 1.20 |
| Wound made in May | 3.44 | 3.52 | 3.00 | 2.18 | 13.8 | 1.18 |
| Wound made in August | 3.05 | 3.68 | 3.42 | 1.91 | 11.2 | 1.27 |
| Least Significant Difference at .05 | 0.15 | 0.17 | 0.16 | 0.19 | 6.0 | 0.09 |
| .01 | 0.20 | 0.23 | 0.21 | 0.25 | 7.9 | — |
| .001 | 0.26 | 0.29 | 0.27 | 0.32 | 10.2 | — |

*Rating for healing of wounds: 1.00, no healing; 2.00, wound only partly covered by callus; 3.00, wound covered but union of tissues not complete; and 4.00, healing apparently complete.

**Rating for vigor of new shoots: 1.00, branch dead or broken off at girdle; 2.00, no new shoots or very short weak shoots; 3.00, shoot growth intermediate, 5 to 10 inches total linear growth per terminal of 1944; 4.00, shoots strong and vigorous, 11 inches or more total linear growth per terminal of 1944.

†Rating for swelling of stem resulting from wound: 1.00, no swelling; 2.00, slight amount of swelling; 3.00, diameter of branch at wound one and one quarter to one and one half times that above and below affected area; and 4.00, diameter of branch at wound more than one and one-half times that above and below the affected area.

healed better than those made by other combinations of factors; however, there were interactions which must be taken into consideration. The differences in healing between wounds made by scoring only and those made by removal of a strip of bark were greater if the wounds were left uncovered than if the wound was protected from desiccation, and also if the wounds were made in August than if made in May (Table II). These interactions and the second-order interaction of the same factors with date of girdling show that the best healing resulted in the case of wounds made in August by scoring only and protected from desiccation (Table III).

Data on wound healing as of October 1946 showed that healing had progressed, reducing the differences between treatments involving severity of wound, protection and date, but increasing the difference

TABLE II—EFFECT OF FIRST-ORDER INTERACTIONS UPON RATINGS FOR HEALING OF WOUNDS AS OF MAY 1945*

| Treatment | Bark Removed From Girdle (Rating) | Girdle Scored Only (Rating) |
|---|---|---|
| *Severity of Wounding With Protection of the Girdle Wound* | | |
| Wound not protected | 2.26 | 3.72 |
| Wound protected | 3.22 | 3.76 |
| *Date of Wounding With Severity of the Wound* | | |
| Girdled in May | 3.22 | 3.65 |
| Girdled in August | 2.26 | 3.84 |

Least significant difference at .05, 0.22; at .01, 0.29; at .001, 0.37.
*Rating scales same as in Table I.

TABLE III—THE EFFECT OF SECOND-ORDER INTERACTION OF DATE, SEVERITY, AND PROTECTION, UPON RATINGS FOR THE HEALING OF GIRDLING WOUNDS, AS OF MAY 1945*

| Treatment | Bark Removed From Girdle (Rating) | | Girdle Scored Only (Rating) | |
|---|---|---|---|---|
| | Wound Not Protected | Wound Protected | Wound Not Protected | Wound Protected |
| Girdle made in May | 3.19 | 3.26 | 3.76 | 3.54 |
| Girdle made in August | 1.34 | 3.19 | 3.69 | 3.99 |

Least significant difference at .05, 0.31; at .01, 0.40; at .001, 0.52.
*Rating scale same as in Table I.

between the methods of girdling. At that time, however, branches girdled in August had healed better than had those girdled in May.

*Growth and Vigor of New Shoots:*—Growth and vigor of the new shoots produced from the terminals on the branches above the girdle are a measure of the degree to which the branch has recovered from the effect of the wounds. The vigor of new shoots as recorded in May of the year following the wounding of the stem was roughly proportional to the degree of healing of the wounds, except that wounds made in May, while healing better, resulted in less vigorous shoots than wounds made in August (Table I).

*Swelling Above the Girdle:*—A wound transverse to a woody stem extending to or through the cambium results in proliferation of cells distal to the wound, causing a localized swelling. The amount of swelling above the girdles in this experiment was in general inversely proportional to the healing of the wounds, that is, wounds that healed rapidly caused little or no swelling while wounds that healed poorly developed much swelling.

The average rating of swelling above girdles made by removal of a strip of bark was greater than above girdles made by scoring only (Table I). Swelling was also greater above girdles made as a closed ring than above those made in a helical form. Contrary to the general relation with rate of healing, swelling was greater above girdles made in May than above gridles made in August.

*Survival of Girdled Branches:*—One of the main objects of this study was to obtain more information of the effect of the different methods of girdling upon the survival of the girdled branches. Forty of the 320 branches girdled in this experiment failed to survive the treatment. An over-all average of 18.8 per cent of the branches girdled with a closed ring, 18.1 per cent of those girdled by removal of a strip of bark, and 18.1 per cent of those with the wound unprotected failed to survive (Table I); and when the three factors were used together 43.7 per cent failed (Table IV). Conversely helical girdling, scoring only with the knife, and wound protection resulted in maximum survival; only 1.3 per cent of the branches girdled by combination of these three practices failed to survive. The combination of any two of the latter treatments tended to reduce the deleterious effect of the opposing treatment of the third factor (Table V).

*Number of Fruit Set:*—Time did not permit counting the number

TABLE IV—THE PERCENTAGE OF GIRDLED BRANCHES FAILING TO SURVIVE, INTERACTION OF SEVERITY, PROTECTION, AND METHOD OF GIRDLING ON SURVIVAL OF GIRDLED BRANCHES

| Treatment | Girdle a Closed Ring (Per Cent) | | Girdle a Helix (Per Cent) | |
|---|---|---|---|---|
| | Bark Removed From Girdle | Girdle Scored Only | Bark Removed From Girdle | Girdle Scored Only |
| Wound not protected | 43.7 | 13.8 | 8.8 | 6.2 |
| Wound protected | 11.2 | 6.3 | 8.7 | 1.3 |

Least significant difference at .05, 12.0; at .01, 15.8; at .001, 20.4.

of pistillate flowers on each of the girdled branches during the blooming period in the spring of 1945, but counts of the number of fruit set were made in May 1945. On non-girdled branches, practically 100 per cent of the pistillate flowers set fruit[2] and fruit counts may be regarded as close estimates of the number of pistillate flowers differentiated. It is not certain that this holds true for the ringed branches.

TABLE V—EFFECT OF THE FIRST-ORDER INTERACTIONS UPON THE PERCENTAGE OF BRANCHES FAILING TO SURVIVE

| Treatment | Bark Removed From Girdle (Per Cent) | Girdle Scored Only (Per Cent) |
|---|---|---|
| *Interaction of Severity With Protection of Wounds* | | |
| Wound not protected | 26.2 | 10.0 |
| Wound protected | 10.0 | 3.8 |
| *Interaction of Severity With Method of Girdling* | | |
| Girdle a closed ring | 27.5 | 10.0 |
| Girdle a helix | 8.8 | 3.8 |
| | Girdle a Closed Ring (Per Cent) | Girdle a Helix (Per Cent) |
| *Interaction of Method of Girdling With Protection of Wounds* | | |
| Wound not protected | 28.8 | 7.5 |
| Wound protected | 8.8 | 5.0 |

Least significant difference at .05, 8.5; at .01, 11.2; at .001, 14.4.

The over-all average number of fruits set in 1945 on the girdled branches bearing fruit in 1944 was 1.15, and on the girdled defruited branches was 1.30, a difference supported by an F value of 12.53, where 11.97 is required for significance at the .001 level. This is in agreement with observation on ungirdled branches in the orchard (2). However, the girdling treatments had little or no effect on the set on fruiting branches. The mean number of fruit set on the fruiting ungirdled check branches was 1.04,[3] on the fruiting closed ringed branches 1.10, and on the comparable defruited ringed branches, 1.34 (Table VI). This is in agreement with the report of Shaw (3) on the effect of ringing apple trees.

Painter and Brown (1) state that swelling of the stem above the

[2]Kilby, W. W. Unpublished data.

[3]Data from the check branches were not included in the analysis of variance; the mean value is derived from 40 observations as are the other data of Table VI and are considered to be of comparable reliability.

TABLE VI—THE EFFECT OF THE METHOD OF GIRDLING AND OF FRUITING IN 1944 UPON THE MEAN NUMBER OF FRUITS PER TERMINAL IN 1945

| | Girdle a Closed Ring (No.) | Girdle a Helix (No.) | Check, Not Girdled (No.) |
|---|---|---|---|
| Branches bearing in 1944 . . . . . . | 1.10 | 1.20 | 1.04 |
| Branches defruited in 1944. . . . . . | 1.34 | 1.27 | — |

Least significant difference at .05, 0.12; at .01, 0.16; at .001, 0.21.

girdle is the best criterion of the effectiveness of the girdle. In the present study, there was no significant correlation between the swelling of the stem above the ring and the number of fruits set per terminal bud, as a correlation coefficient of 0.083 was found between these two factors, while a coefficient of 0.159 is needed for significance at the .05 level.

## SUMMARY

Wounds on girdled tung branches healed better, less swelling developed above the girdle, and the branches survived better if the girdle was made by merely scoring with parallel knife cuts, as compared with the removal of a strip of bark between similarly made knife cuts.

Wounds in the form of a helix healed better, less swelling developed, and the branches survived better than in the case of wounds made as a closed ring.

Wounds on girdled tung branches healed better, less swelling developed above the wound, and the branches survived better if the girdle was protected from desiccation by covering with waxed tape or electricians' tape.

Wounds on branches girdled in May started to heal promptly, but at the final observation wounds made in August had healed as well as or better than those made in May.

Girdling of tung branches did not significantly affect the number of fruit set the following season.

A greater number of fruit set in 1945 on the new terminals of tung branches that were girdled and defruited in 1944 than on similar girdled branches bearing fruit in 1945.

## LITERATURE CITED

1. PAINTER, JOHN H., and BROWN, RALPH T. Effect of different methods of girdling tung branches. *Proc. Amer. Soc. Hort. Sci.* 37: 511–514. 1940.
2. POTTER, GEORGE F., SITTON, BENJAMIN G., and MCCANN, LEWIS P. The effect of different rates of application of nitrogen on biennial bearing in tung. *Proc. Amer. Soc. Hort. Sci.* 50: 125–130. 1947.
3. SHAW, J. K. An experiment in ringing apple trees. *Proc. Amer. Soc. Hort. Sci.* 19: 216–220. 1923.
4. YATES, F. The design and analysis of factorial experiments. *Tech. Comm. No. 35. Imp. Bur. Soil Sci.* pp. 23–25. 1937.

# Effect of Low Temperature on Blossom Survival and Fruit Set of Nineteen Varieties of Almonds

By W. H. Griggs, *University of California, Davis, Calif.*

Nineteen forty-eight was an unusually early blooming year for almonds in northern California. At the Wolfskill experimental orchard near Winters the earliest-blooming varieties started blossoming from 2 to 3 weeks earlier than average; the latest blooming ones, 1 to 2 weeks earlier (Table I).

TABLE I—1948 Blossoming Dates of Certain Almond Varieties at Winters, and Average Blossoming Dates for the Same Varieties at Davis, California*

| Variety | First Bloom | | Full Bloom | | Last Bloom | |
|---|---|---|---|---|---|---|
| | 1948 | Average | 1948 | Average | 1948 | Average |
| Harriot | Jan 17 | Feb 8 | Jan 27 | Feb 23 | Feb 11 | Mar 15 |
| Jordanolo | Jan 22 | —— | Feb 3 | —— | Feb 21 | —— |
| Harpareil | Jan 24 | —— | Feb 17 | —— | Feb 20 | —— |
| Jordan | Jan 26 | Feb 17 | Feb 9 | Mar 1 | Feb 20 | Mar 16 |
| Klondike | Jan 26 | Feb 16 | Feb 10 | Mar 1 | Feb 18 | Mar 13 |
| Ne Plus Ultra | Jan 26 | Feb 14 | Feb 17 | Feb 25 | Feb 26 | Mar 14 |
| California | Jan 26 | Feb 16 | Feb 20 | Feb 28 | Feb 26 | Mar 14 |
| Princess | Jan 26 | Feb 16 | Feb 21 | Mar 2 | Feb 26 | Mar 15 |
| Peerless | Jan 30 | Feb 17 | Feb 21 | Mar 1 | Feb 26 | Mar 15 |
| King | Jan 31 | Feb 16 | Feb 17 | Mar 1 | Feb 23 | Mar 14 |
| Lewelling | Jan 31 | Feb 17 | Feb 20 | Mar 1 | Feb 26 | Mar 15 |
| La Marie | Feb 4 | —— | Feb 21 | —— | Feb 28 | —— |
| Drake | Feb 9 | Feb 19 | Feb 23 | Mar 7 | Mar 1 | Mar 18 |
| IXL | Feb 11 | Feb 15 | Feb 19 | Feb 26 | Feb 26 | Mar 13 |
| Nonpareil | Feb 11 | Feb 18 | Feb 23 | Mar 3 | Mar 1 | Mar 15 |
| Eureka | Feb 12 | Feb 21 | Feb 26 | Feb 26 | Mar 2 | Mar 10 |
| Texas | Feb 17 | Feb 26 | Feb 26 | Mar 10 | Mar 2 | Mar 21 |
| Languedoc | Feb 17 | Feb 26 | Feb 26 | Mar 10 | Mar 3 | Mar 20 |
| Reams | Feb 23 | Mar 1 | Mar 2 | Mar 12 | Mar 5 | Mar 22 |

*Average dates are from California Agricultural Experiment Station Bulletin 346.

The almond variety orchard at Wolfskill consists of two trees of each variety growing in Yolo sandy loam, and each variety is adjacent to another variety with a similar blossoming period in order to favor cross-pollination. The trees, planted in 1939, are fairly uniform, moderate in vigor and have produced three commercial crops.

The low temperatures between January 27 and February 5 (Table II) afforded an opportunity to study the comparative cold resistance of the almonds since 12 of the varieties were blooming during that period, and others bloomed shortly thereafter.

Blossoms were collected and examined for low temperature injury from all trees included in the study. Collection was started February 5 and continued through February 9. Each sample consisted of approximately 300 blossoms. Although during the period when the freezes occurred the blooming status of the trees varied from unopened blossoms to full bloom (Tables I and II), there were still enough unopened blossoms for samples on even the earliest blooming varieties. Therefore, both opened and unopened blossoms were gathered from the early-blooming varieties (totaling approximately 1200 blossoms per tree) while only unopened blossoms were gathered from the later-blooming ones (approximately 600 blossoms per tree). Flowers in the

TABLE II—LOW TEMPERATURES FROM JANUARY 27, 1948 THROUGH FEBRUARY 9, 1948 IN THE ALMOND VARIETY ORCHARD, WOLFSKILL EXPERIMENTAL ORCHARD, WINTERS, CALIFORNIA*

| Date (A M) | Minimum Temperature (Degrees F) | Approximate Duration (Hours) | Additional Notations of Freezing Temperatures |
|---|---|---|---|
| Jan 27 | 38 0 | – | |
| Jan 28 | 23.0 | 2 | 25 degrees F or below for 6 hours |
| Jan 29 | 25.5 | 1½ | 27 degrees F or below for 4 hours |
| Jan 30 | 27.0 | 1 | 28 degrees F or below for 2 hours |
| Jan 31 | 25.5 | 1 | 26 degrees F or below for 3 hours |
| Feb 1 | 38.0 | – | |
| Feb 2 | 22.5 | 2 | 25 degrees F or below for 4 hours |
| Feb 3 | 32.7 | – | |
| Feb 4 | 27.2 | 2 | 29 degrees F or below for 5 hours |
| Feb 5 | 31.0 | 4 | 32 degrees F or below for 5 hours |
| Feb 6 | 34.2 | – | |
| Feb 7 | 29.5 | 1 | 30 degrees F or below for 2 hours |
| Feb 8 | 29.7 | 1 | 31 degrees F or below for 4 hours |
| Feb 9 | 44.7 | – | |

*Data were obtained from a minimum thermometer and a thermograph, located in the orchard 4 feet above the ground.

popcorn stage were selected for the unopened blossom samples. In collecting either opened or unopened blossoms, a sample was gathered at random from the lower branches up to about 7½ feet around each tree, and another sample was taken from the 7½ foot line to their tops. Immediately after sampling, the flowers were examined for cold injury by cutting through the ovary with a small pair of scissors.

To give a further indication of survival of the blossoms, a branch was selected on the south side of each tree about 7½ feet from the ground to determine fruit set. The numbers of blossoms on these branches were recorded and counts of fruit set were made May 14.

Table III shows the survival of the blossoms and the fruit sets on the open pollinated branches. The survival data for the unopened, opened and total numbers of blossoms examined were statistically analyzed and are presented separately with the hypotheses that (a) the survival of opened blossoms would help classify the early-blooming varieties according to their resistance to low temperature; (b) the survival of the unopened blossoms, since they were in approximately the same stage of maturity, would show the relative inherent cold resistance of all the varieties in spite of variations in the time of opening of most of their blossoms; and (c) the survival of both opened and unopened blossoms would give a comparison of the low temperature resistance of all varieties regardless of blooming date, which is of primary concern to the grower.

Of the varieties from which opened blossoms were examined, the means of survival for Harpareil (79.0 per cent), Jordanolo (52.0 per cent) and Ne Plus Ultra (51.8 per cent) show greater resistance to low temperature than those for Klondike (34.6 per cent), Jordan (11.9 per cent) or Harriot (2.6 per cent). When compared on the basis of unopened blossoms, Harpareil, Jordanolo and Ne Plus Ultra again show higher means for survival (95.2 per cent, 97.0 per cent and 78.8 per cent respectively) than Klondike (63.2 per cent), Harriot (44.3 per cent) and Jordan (32.8 per cent). The early blooming of

TABLE III—SURVIVAL OF ALMOND BLOSSOMS FOLLOWING LOW TEMPERATURES, AND SUBSEQUENT FRUIT SET (MEANS FOR POSITION ARE FOR ALL TREES; MEANS FOR VARIETIES ARE FOR TWO TREES)

| | No. Opened Blossoms Examined | Mean Survival Per 100 Blossoms | No. Unopened Blossoms Examined | Mean Survival Per 100 Blossoms | Total No. Blossoms Examined | Mean Survival Per 100 Blossoms | No. Blossoms on Open Pollinated Branches | Mean Set Per 100 Blossoms (May 14, 1948) |
|---|---|---|---|---|---|---|---|---|
| Position | | | | | | | | |
| 7.5 ft—top | 3,553 | 42.5 | 10,858 | 86.0 | 14,411 | 75.2 | — | — |
| Ground—7.5 ft. | 3,442 | 33.7 | 10,867 | 82.3 | 14,309 | 70.6 | — | — |
| Difference required for significance | | | | | | | | |
| 5.0 per cent level | — | 1.8 | — | 1.2 | — | 2.4 | — | — |
| 1.0 per cent level | — | 2.8 | — | 1.6 | — | 3.2 | — | — |
| Variety (order of blooming for 1948) | | | | | | | | |
| Harriot | 1,240 | 2.6 | 1,144 | 44.3 | 2,384 | 22.6 | 945 | 1.2 |
| Jordanolo* | 903 | 52.0 | 536 | 97.0 | 1,439 | 68.8 | 282 | 13.5 |
| Harpareil | 1,239 | 79.0 | 1,259 | 95.2 | 2,498 | 87.2 | 1,768 | 33.9 |
| Jordan | 1,200 | 11.9 | 1,223 | 32.8 | 2,423 | 22.4 | 833 | 5.2 |
| Klondike | 1,200 | 34.6 | 1,230 | 63.2 | 2,430 | 49.0 | 690 | 11.3 |
| Ne Plus Ultra | 1,213 | 51.8 | 1,253 | 78.8 | 2,466 | 65.6 | 1,219 | 30.3 |
| California | — | — | 1,209 | 49.8 | 1,209 | 49.8 | 947 | 21.0 |
| Princess | — | — | 1,200 | 81.0 | 1,200 | 81.0 | 847 | 18.8 |
| Peerless | — | — | 1,200 | 88.8 | 1,200 | 88.8 | 846 | 29.2 |
| King | — | — | 1,200 | 93.9 | 1,200 | 93.9 | 897 | 35.0 |
| Lewelling | — | — | 1,217 | 99.2 | 1,217 | 99.2 | 953 | 29.4 |
| La Marie | — | — | 1,200 | 100.0 | 1,200 | 100.0 | 908 | 30.8 |
| Drake | — | — | 1,205 | 99.6 | 1,205 | 99.6 | 996 | 25.2 |
| I.X.L.* | — | — | 648 | 79.5 | 648 | 79.5 | — | — |
| Nonpareil | — | — | 1,200 | 99.9 | 1,200 | 99.9 | 1,017 | 29.7 |
| Eureka | — | — | 1,200 | 100.0 | 1,200 | 100.0 | 1,023 | 14.0 |
| Texas | — | — | 1,200 | 100.0 | 1,200 | 100.0 | 1,007 | 36.7 |
| Languedoc | — | — | 1,201 | 99.9 | 1,201 | 99.9 | 850 | 21.5 |
| Reams | — | — | 1,200 | 99.8 | 1,200 | 99.8 | 813 | 28.7 |
| Total | 6,995 | | 21,725 | | 28,720 | | 16,841 | |
| Difference required for significance | | | | | | | | |
| 5.0 per cent level | | 5.6 | | 3.6 | | 7.3 | | 12.2 |
| 1.0 per cent level | | 8.7 | | 5.0 | | 10.0 | | 16.8 |

*One tree only.

the Harriot trees offers an explanation for their low blossom survival, but the order of blooming does not explain the differences in the survival of the other varieties.

In general, however, the mean survival of unopened blossoms increased on the later blooming varieties. With the exception of IXL, practically all flowers survived on all varieties which were not in bloom during the period when the freezes occurred. The fact that California had a significantly lower survival of unopened blossoms (49.8 per cent) than either Princess (81.0 per cent) or Ne Plus Ultra (78.8 per cent), even though their blooming dates were the same, seems to indicate less resistance for this variety.

The effect of gradient air temperatures is shown by a significantly higher survival of both opened and unopened blossoms from the upper portion of the trees.

Taylor (1) in California found that almond blossoms just opening withstood temperatures as low as 24 degrees F, but that in all cases known to him blossoms with the petals falling were killed by a temperature of 30 to 31 degrees F. Wood (2), working in the same State

reported that almond blossoms often endured 26 to 28 degrees F for a short time, but were damaged after a number of hours at this temperature. He further noted that blossoms of some varieties, such as Nonpareil, withstood more frost in the early opening stage than Peerless.

It is noteworthy in view of the above reports that the first six varieties listed in Table III had open blossoms exposed to 23 degrees F on January 28 and 22.5 degrees F February 2 with means of survival ranging from 2.6 per cent for Harriot to 79.0 per cent for Harpareil.

The correlation coefficients between fruit set and survival of unopened blossoms (0.70) and between fruit set and survival of all blossoms examined (0.72) were both highly significant ($P<0.01$) and show the close relationship of these factors. It should be noted that the orchard was well provided with bees, and that throughout the blooming season there was usually a period during each day when weather conditions were favorable for insect activity.

Thus, under the conditions of this study, the resistance of almond blossoms to low temperatures depended largely upon their stage of maturity, but the importance of inherent cold resistance was also indicated by significant differences in survival and set among varieties with essentially the same blooming dates.

## Literature Cited

1. Taylor, R. H. The almond in California. *Calif. Agr. Exp. Sta. Bul.* 297. 1918.
2. Wood, M. N. Almond culture in California. *Calif. Agr. Ext. Cir.* 103. Rev. 1947.

# Defoliation of Montmorency Sour Cherry Trees in Relation to Winter Hardiness[1]

By W. C. KENNARD, *The Pennsylvania State College, State College, Penn.*

IN recent years partial or complete defoliation of sour cherry trees has become a serious problem in the cherry-growing sections of Pennsylvania and other states.

Defoliation is the result of many factors, the foremost of which is cherry leaf spot *Coccomyces hiemalis* Higgins, the control of which is well described by Keitt, *et al* (5). Lewis and Groves (6) pointed out that although difficult to control completely, defoliation due to cherry leaf spot can be effectively checked by the use of the proper materials applied at the correct time. Rasmussen (9) pointed out, however, that not all causes of defoliation can be controlled by spraying; other factors such as fertilizer treatments, drought injury, virus diseases, insect injury, and spray injury often cause defoliation.

The defoliation caused by these several factors may occur very early in the growing season and is generally believed to result in increased susceptibility to winter injury. Gloyer and Glasgow (3) found that in some years, because of defoliation, winter killing of branches of Montmorency trees may occur. Horsfall and Vinson (4) defoliated branches of Grimes Golden, Winesap, and Stayman Winesap apple trees and found that defoliation retarded opening of leaf and flower buds in the following spring; the degree of retardation was less the later the branches were defoliated in the preceding fall. They concluded that the reduced carbohydrate supply resulting from premature loss of leaves is likely to increase susceptibility to injury from low temperatures.

Following several years of partial or complete defoliation, the low temperatures of the winter 1945–1946 caused the death of many Montmorency trees in the cherry-growing section of south-central Pennsylvania. The object of this experiment was to determine the resistance to low winter temperatures of Montmorency sour cherry trees defoliated manually in various amounts at different times during the growing season of 1947.

## MATERIALS AND METHODS

*Description of Orchard:*—The cherry block at the Pennsylvania State College consists of about 90 trees which are 16 years and 30 trees which are 30 years old, all of the Montmorency variety, selected for the experiment because it is by far the leading commercial sour cherry variety in Pennsylvania. The soil is Hagerstown silty clay loam which contains a fair amount of organic matter (about

[1]Authorized for publication on September 2, 1948, as paper No. 1468 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

3 per cent) and mineral plant nutrients. It has a brown surface and a reddish-brown, moderately heavy but permeable subsoil.

The trees in this block have received the usual orchard treatment and have been sprayed regularly each year. As a result they have not been previously winter injured in consequence of defoliation by leaf spot. This cherry block is comparable to healthy and productive commercial orchards in the state.

*Defoliation Plan:*—In order to find the effect on winter hardiness of defoliation at different times during the preceding summer, matched pairs of trees were selected, one to be defoliated and the other to remain as a check. In the sour cherry, buds of the current season's wood are of two types, flower or vegetative. Only the vegetative buds produce spurs the following season. In this experiment trees of two different types of growth were used; first, those on which there was a well distributed number of spurs on the older wood and, second, those on which the buds were so predominantly fruitful that the older wood had practically no spur growth. Trees of the first type were designated as "spur-wood" and trees in the latter condition were designated as "blank-wood" in this report. Since all trees received the same treatment the exact reasons for this difference in type of growth are not known; inasmuch as the difference exists, however, it was thought best to include both types in the experiment. Trees of a pair were adjacent to avoid, as much as possible, any soil irregularities which may have existed; they were of the same type of growth and had similar trunk circumferences measured 12 inches from the ground; and each pair had tops similar in size. The trees were divided into sets of three pairs of trees and were defoliated according to the plan shown in Table I. The defoliated trees

TABLE I—DEFOLIATION PLAN

| Treatment and Type of Growth* | Amount of Foliage Manually Removed in 1947 During | | | |
|---|---|---|---|---|
| | Jun 25–30 (Per Cent) | Jul 25–30 (Per Cent) | Aug 10–15 (Per Cent) | Sep 1 (Per Cent) |
| A Spur-wood | 25 | 25 | 25 | 25 |
| B Blank-wood | 25 | 25 | 25 | 25 |
| D Spur-wood | 33 | 33 | 33 | — |
| E Blank-wood | 33 | 33 | 33 | — |
| J Blank-wood (plus $NaNO_3$) | 33 | 33 | 33 | — |
| G Blank-wood | — | 12 | 38 | — |
| H Blank-wood (plus $NaNO_3$) | — | 12 | 38 | — |

*Each treatment is designated by a letter and consists of three pairs of trees.

in sets H and J each received an application of 4 pounds of nitrate of soda on August 1, 1947, to determine whether nitrogenous fertilizer would delay maturity and thus increase susceptibility to winter injury. All trees were 16 years old except those in set A which were 30 years old. In order to avoid injury and to control the number of leaves removed from a tree at any one time, the trees were not defoliated by use of chemicals but were defoliated by hand with small thinning shears.

*Description of Apparatus and Freezing Tests:*—The apparatus used in freezing twigs consisted of an insulated freezing chamber of galvanized iron 28 inches long, 12 inches wide, and 14 inches deep. A Ranco type "O" manually operated thermostat, accurate to ± 1 degree F was used to control temperatures within the box. Freon was used as the refrigerant. Temperatures were measured by several thermometers placed at different levels in the freezing compartment. Inasmuch as the samples occupied only the lower 2 inches of the box, stratification of air was deemed unimportant and a fan was not used.

Twigs used in this experiment were taken at random from each of the trees, no two twigs being taken from the same branch. Twigs selected were cut about 6 inches long. When the terminal growth was less than that length some 2- and even 3-year-old wood was included to make the sample 6 inches long; in all cases, however, only 1-year-old wood was examined after freezing.

Preliminary freezing tests made in December, 1947, showed that temperatures above 15 degrees F caused no appreciable injury, while lower temperatures resulted in injury. Twigs for the first freezing test were cut on January 3, 1948, and placed in the freezing box at 15 degrees F. Twigs for the second freezing test were cut on January 18, 1948, placed in cold storage at about 33 degrees F overnight, and then placed in the freezer at 15 degrees F. In both cases the twigs required 15 to 30 minutes to reach 15 degrees F and then the temperature was lowered further. Since Carrick (1) and Chandler (2) found that the rate of freezing is a factor in determining the degree of injury in plant tissue—the faster the rate of freezing, the greater the injury—the temperature of the freezing compartment was gradually lowered 2½ degrees per hour until the desired minimum had been reached. One twig from each tree was removed at 5-degree intervals as the temperature was lowered. In view of the fact that Chandler (2) and Potter (8) concluded that the rate of thawing has no influence on the amount of freezing injury of most plant tissues, the twigs were placed on tables in the laboratory at room temperature, 70 to 72 degrees F, and allowed to thaw for 2 to 4 hours before they were examined to determine the extent of injury. Examinations were made both visually and with a low-power binocular microscope; brown discolorations of the pith, xylem, and phloem tissues and buds were used as criteria of injury. An arbitrary value of 1 was assigned for slight injury and 2 for severe injury, making 8 the greatest possible total injury for a single twig when all four parts were included in the examination.

The winter of 1947–48 was unusually severe; a temperature of –15 degrees F on January 19, 1948, and of –18 degrees F on January 30, 1948, caused so much damage to wood and buds of the cherry trees that freezing tests were discontinued; to determine the extent of injury caused by the naturally occurring temperatures, however, twigs were cut and examined from each of the trees on February 4, 1948, and again on April 11, 1948.

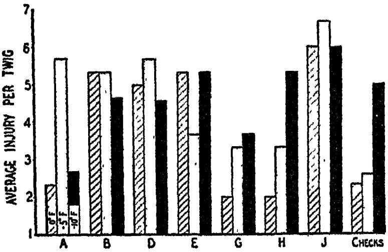



Fig. 1. Injury sustained by cherry twigs frozen to 0 degree, —5 degrees, and —10 degrees F on January 3, 1948. The following figures indicate minimum levels of significance: 1.27 for 0 degree, 1.79 for —5 degrees, and 2.02 for —10 degrees.

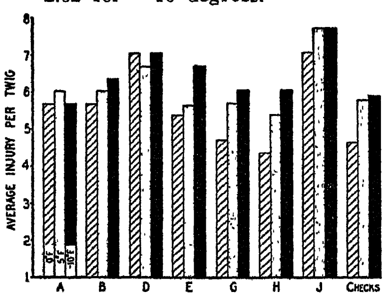



Fig. 2. Injury sustained by cherry twigs frozen to 0 degrees, —5 degrees, and —10 degrees F on January 18, 1948. The following figures indicate minimum levels of significance: 0.99 for 0 degree, 1.05 for —5 degrees, and 0.90 for —10 degrees.

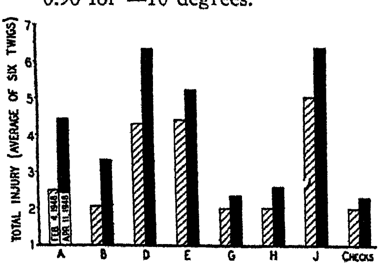



Fig. 3. Injury sustained by cherry twigs as a result of naturally occurring low temperatures. Twigs examined February 4 and April 11, 1948. The following figures indicate minimum levels of significance: 0.47 for twigs examined February 4 and 1.42 for twigs examined April 11.

## Results

The first results of defoliation were evident early in September, 1947. At that time both spur-type and blank-wood type trees which had been completely defoliated by August 10 developed new leaves and blossoms in equal amounts. Trees completely defoliated by September 1 and trees 50 per cent defoliated by August 10 did not develop new leaves or blossoms. In order to determine accurately the proportion of the total injury resulting from each treatment, the means of the injuries were plotted (Figs. 1, 2, and 3) and the data were subjected to analyses of variance as outlined by Paterson (7). Differences in height of columns necessary for significance are given under each table. Statistical analyses of the different temperatures within each freezing test are not presented. An analysis of the check trees showed that no significant difference in susceptibility to low temperature injury existed between blank-wood and spur-wood trees; therefore, all check trees were grouped together and averaged when comparisons were made among treatments.

Minimum temperatures for one week before January 3, 1948, ranged from 14 to 32 degrees F. Twigs were greatly injured when artificially frozen on that date. Temperatures between January 3 and January 18, 1948, ranged from 0 to 25 degrees F, yet the twigs artificially frozen on January 18 were more severely injured than those frozen on January 3. The reason for the failure of the twigs to be more hardy after continued moderately cold temperatures is unknown.

Twigs collected on February

4, 1948, showed less severe injury than those artificially frozen on January 3 and January 18 indicating that the prevailing lower temperatures had increased winter hardiness of both buds and twigs.

Twigs examined on April 11, 1948, showed slightly more injury than that which appeared on February 4 indicating that during the interim another critically low temperature occurred, probably the –12 degree F temperature of February 9.

Observations in the orchard on May 1, 1948, showed that outstanding differences existed among trees of different treatments and check trees. Trees which were completely defoliated by August 10, 1947, had no blossoms; trees which were completely defoliated by September 1, 1947, had about one-half of the usual number of blossoms; and check trees were in full bloom. Trees which were 50 per cent defoliated by August 10, 1948, also were in full bloom.

## Summary

1. Complete defoliation increased the susceptibility of Montmorency sour cherry trees to low temperature injury and delayed blossoming in the following spring.

2. Trees completely defoliated by August 10 were more severely injured than those completely defoliated by September 1, 1947.

3. Fifty per cent defoliation by August 10, 1947, did not increase the amount of low temperature injury in comparison with check trees.

4. Nitrate of soda, at least in quantities up to 350 pounds per acre applied on August 1, did not increase the amount of injury on trees 50 per cent defoliated by August 10, 1947. The same application, however, increased low temperature injury on trees completely defoliated by August 10, 1947.

5. No differences were found between trees of "blank-wood" growth and "spur-wood" growth.

6. These results indicate the serious effects of defoliation and emphasize the importance of greater care in preventing premature defoliation.

## Literature Cited

1. Carrick, D. B. Resistance of roots of some fruit species to low temperature. *N. Y. (Cornell) Exp. Sta. Memoir* 36. 1920.
2. Chandler, W. H. The killing of plant tissue by low temperature. *Mo. Agr. Exp. Sta. Res. Bul.* 8: 141–309. 1913.
3. Gloyer, W. O., and Glasgow, H. Defoliation of cherry trees in relation to winter injury. *N. Y. Agr. Exp. Sta. Bul.* 555. 1928.
4. Horsfall, F., Jr., and Vinson, C. G. Hardiness investigations with the apple. *Mo. Agr. Exp. Sta. Res. Bul.* 289. 1938.
5. Keitt, G. W., Blodgett, E. C., Wilson, E. E., and Magie, R. O. The epidemiology and control of cherry leaf spot. *Wisc. Agr. Exp. Sta. Res. Bul.* 132. 1937.
6. Lewis, F. H., and Groves, A. B. Control of cherry leaf spot in the Cumberland-Shenandoah Valley. *Penn. Agr. Exp. Sta. Bul.* 498. 1948.
7. Paterson, D. D. Statistical Technique in Agricultural Research. McGraw-Hill Book Co. New York. 1939.
8. Potter, G. F. Experiments on resistance of apple roots to low temperatures. *N. H. Agr. Exp. Sta. Tech. Bul.* 27. 1924.
9. Rasmussen, E. G. Causes of premature defoliation of sour cherry. *Ore. State Hort. Soc. Rep.*: 131–137. 1938.

# Lesion Nematode Injury to California Fruit and Nut Trees, and Comparative Tolerance of Various Species of Juglandaceae

By E. F. SERR and L. H. DAY, *University of California, Davis, Calif.*

THE Lesion or Meadow Nematode (*Pratylenchus pratensis*) has been found widely scattered in California by United States Department of Agriculture and Experiment Station workers. In 1941 we found it associated with die-back of bearing sweet cherry trees in Riverside County. About the same time it was found on walnut trees showing poor vigor in Ventura County.[1] Since then it has been identified on walnuts in several Southern California counties and also in the San Joaquin, Sacramento, and Santa Clara Valleys. Fig and olive roots have been reported frequently infested with this nematode. Apple, almond, peach, pear, plum, and quince roots have been reported infested in at least a few cases.[2]

It is now apparent that the lesion nematode is doing serious damage to commercial English (Persian) walnut and sweet cherry orchards in several districts in California. Less is known of the extent of the damage caused by this nematode to other species of fruits and nuts, although some cases of low tree vigor have been observed associated with a high population of the nematode and characteristic symptoms.

This paper discusses observations of lesion nematode damage in California orchards, and reports progress of some tests of various species of Juglandaceae for resistance or tolerance, and initiation of other tests of various fruit and nut species and varieties.

## NATURE OF THE INJURY

Mature walnut and sweet cherry trees severely attacked by *Pratylenchus pratensis* are observed to make weak, sparce growth, followed by dying back of twigs or branches at the ends of main limbs (Fig. 1). Examination of roots of such trees shows that many of the small fibrous roots have been killed. The scarcity of live feeder roots is very noticeable. In some species, such as *Juglans hindsii,* large lesions or cankers are easily found on roots ranging from about ¼ inch up to 6 inches or more in diameter (Fig. 2). These lesions vary in diameter from about ⅛ inch to 2 inches or more, and often develop deep cracks in the killed bark parallel to the axis of the root. The lesions gradually grow deeper and often completely kill the bark

[1]Specimens collected by R. W. Southwick (former County Agent) and examined by Gerald Thorne, United States Department of Agriculture Nematologist.

[2]The writers are indebted to Gerald Thorne, United States Department of Agriculture Nematologist, Salt Lake City and M. W. Allen, University of California, Berkeley, for examination and species determination of many specimens and to R. W. Southwick, M. M. Winslow, C. C. Delphey, G. E. Goodall and G. D. Worswick of the California Agricultural Extension Service for help in establishing and maintaining test plots.

FIG. 1. Decline of Franquette walnut—roots severely injured by the lesion nematode.

within their margins. They have distinct but expanding margins, usually enlarging laterally around the roots faster than longitudinally, and sometimes completely girdling and killing roots. Commonly new roots grow out above the girdled area and the tree is able thus to maintain a weakened root system.

In some districts small trees used as replants in old orchards or planted on land where old trees have been removed recently seem

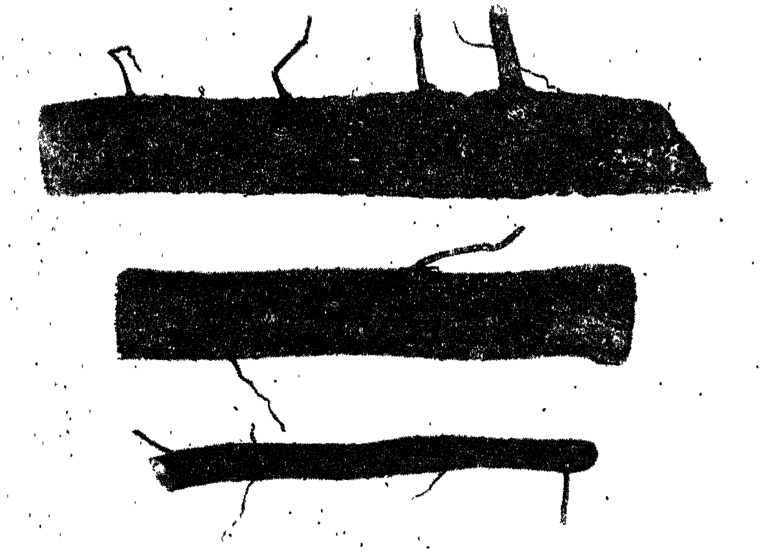


FIG. 2. Roots of *Juglans hindsii* showing large lesions caused by *Pratylenchus pratensis.*

especially subject to severe attack by *Pratylenchus pratensis*. Presumably this is because of a high population of the nematode which has built up on roots of the old trees. In such cases injury to feeder roots of young trees seems similar to injury on old trees but in addition large lesions are often formed on the young trees just below the crown, sometimes completely girdling one or more main roots (Fig. 3).

In our observations to date lesions have been found on roots of walnut, olive, fig, cherry and almond.

## TESTS OF JUGLANDACEAE

*Ventura County*[3]:—In a mature English walnut orchard on *Juglans hindsii* rootstock some of the trees were showing very low vigor and the presence of the lesion nematode had been determined. In April, 1943, four of the weakest trees were pulled and five or six 1-year-old seedling trees of several species of Juglandaceae were planted in a circle about 5 feet in diameter at each former tree location. Early in 1944 four other groups were planted in similar tree locations and in 1945 another group was added. They were given the normal care received by old trees in the orchard.

The seedlings, with the exception of wingnuts (*Pterocarya*), made very poor growth. Root specimen examinations showed *Pratylenchus pratensis* present in large numbers. In February 1948 the trees were measured, pulled by tractor and examined at once. Lesions and severe

[3]This plot was established through cooperation of the Agricultural Extension Service of Ventura County.

FIG. 3. Large lesions near crown and on main roots of walnut seedlings caused by *Pratylenchus pratensis* (margins lightly scraped to emphasize outline)—Above, *Juglans californica*; below, *Juglans hindsii.*

root damage were found on all excepting the wingnuts. Data are given in Table I.

Results indicate outstanding vigor of *Pterocarya stenoptera* (wingnut) and either resistance or tolerance of this species, with no lesions found despite a high population of *Pratylenchus pratensis* in the surrounding soil. Some of the seedlings of each *Juglans* species tested were seriously injured. Root systems of characteristic specimens of each species are shown in Fig. 4.

*Santa Clara County:*—In an English walnut orchard approximately 30 years old, mostly on *Juglans hindsii* rootstock, many trees are in very low vigor and dying back. There are a few trees on Paradox (presumably *J. hindsii* x *J. regia*) and these show outstanding vigor (Fig. 5). On examination we found *J. hindsii* roots had numerous lesions and many small rootlets had been killed. Nematologists found *Pratylenchus pratensis* present on specimens submitted. We found no lesions on

TABLE I—Ventura County Plot (Trees Measured, Pulled and Examined in February, 1948)

| Species | Age of Trees | No. of Trees | Average Height (Feet) | Average Circumference (Inches) | Severity of Injury to Root System (1–5)* |
|---|---|---|---|---|---|
| *Juglans regia* | 5 | 4 | 6.6 | 6.2 | 3.0 |
| *Juglans hindsii* | 5 | 4 | 6.1 | 5.4 | 3.0 |
| *Juglans hindsii* | 3 | 1 | 3.5 | 3.2 | 5 0 |
| *Juglans nigra* | 5 | 4 | 8.8 | 6.6 | 3.5 |
| *Juglans nigra* | 4 | 4 | 4.2 | 3.5 | 4.0 |
| *Juglans californica* | 4 | 4 | 5.8 | 3.9 | 4.3 |
| *Juglans honorei* | 5 | 4 | 4.8 | 4.3 | 4.0 |
| *Juglans* sp. (Mexican black) | 4 | 4 | 3.3 | 3.5 | 4.0 |
| *Juglans sieboldiana* | 4 | 4 | 5.2 | 5.1 | 3.0 |
| *Juglans major* | 4 | 4 | 4.7 | 4.1 | 4.3 |
| *Juglans rupestris* | 4 | 2 | 6.0 | 3.7 | 4.0 |
| *Juglans cinerea* | † | 4 | — | — | — |
| *Pterocarya stenoptera* | 3 | 6 | 13.6 | 7.8 | ‡ |

*Estimates based on number, size and penetration of lesions on main roots and proportions of root system destroyed. The relative resistance (or tolerance) is graded numerically as follows: (1) no appreciable injury, (2) slight injury, (3) moderate injury, (4) severe injury, (5) very severe injury.

†All died after second year but cause not definitely determined.

‡Dr. M. W. Allen found some *Pratylenchus pratensis* in root tips.

Paradox hybrid roots, and small live rootlets were numerous (Fig. 6). In this orchard three 1-year-old interplants of Paradox seedlings were examined in May, 1948 and no lesions were found while three 1-year-old interplants of *J. hindsii* nearby all had damaging lesions on their main roots.

## Test Nurseries

Test nurseries have been established in Riverside County (1945) and Yolo County (1948) in which were planted specimens of most of the common root-stocks used for decidous fruit trees, nuts, olives and grapes. In addition there were included some species and varieties of walnut, cherry, plum, apricot and peach not now used as root-stocks.

In the Riverside plot wingnuts have shown outstanding vigor as compared with walnut species.

## Paradox Hybrids and Wingnuts as Possible Stocks for English Walnut

A few Paradox (*Juglans hindsii* x *J. regia*) hybrid root-stocks can be found in many of the English walnut orchards in California, since they occur naturally in many lots of nursery seedlings of *J. hindsii*. In our experience they have been at least as satisfactory as *J. hindsii* although their relative resistance to oak root fungus (*Armillaria mellea*) has not been fully determined. In some cases their greater vigor has been a decided advantage.

The question of use of one or more species of *Pterocarya* (Wingnut) as rootstocks for English walnut has been given some attention. There is one 9-year-old English walnut tree on *P. stenoptera* in the Plant Introduction Gardens, Chico, making excellent growth reported by Whitehouse and Joley (1). There are two nursery budded trees in


FIG. 4. Crowns and roots of typical specimens of *Juglandaceae* species grown in orchard heavily infested with *Pratylenchus pratensis* in Ventura County. 1, Juglans sp. (Mexican); 2, *J. rupestris;* 3, *J. seiboldiana;* 4, *J. honerei;* 5, *J. major;* 6, *J. nigra;* 7, *J. californica;* 8, *J. hindsii;* 9, *J. regia;* and 10, *Pterocarya stenoptera.*

FIG. 5. 30-year-old vigorous Payne walnut on Paradox rootstock (left) next to declining tree of same age and variety on *Juglans hindsii* rootstock.

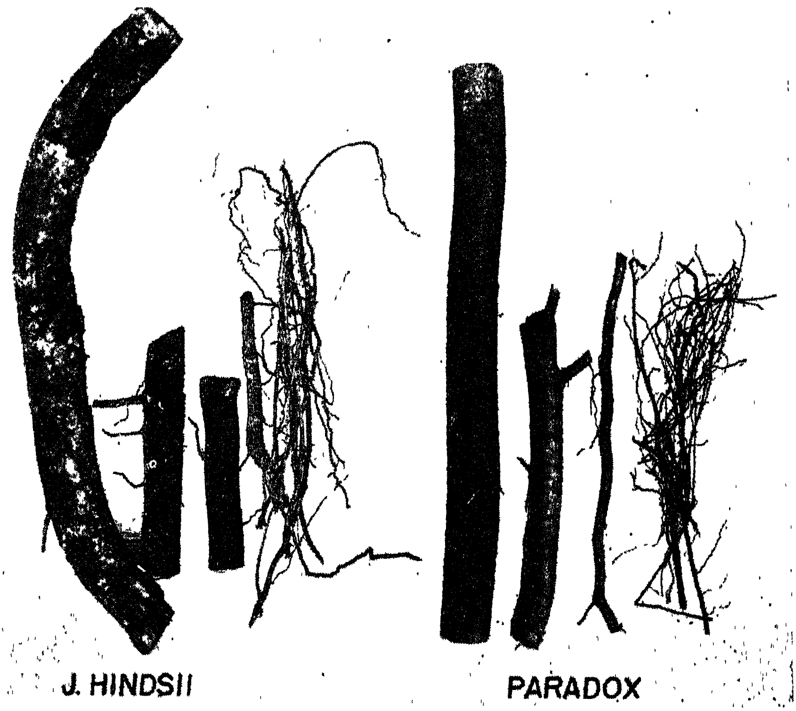



FIG. 6. *Juglans hindsii* roots showing many lesions (left) compared with Paradox hybrid roots on adjoining tree.

the Station orchard at Davis with tops in their fourth growing season and three orchard budded trees with tops in their third season. Thorough testing of this combination will require many years. Fifty wingnut seedlings were distributed to growers in small lots in February, 1948, for widespread trials.

## SUMMARY

Lesion nematode (*Pratylenchus pratensis*) is causing serious injury to fruit and nut trees in several fruit districts in California. Extensive trials to determine resistance or tolerance of many species are under way. Preliminary tests of 12 species and hybrids of Juglandaceae, have indicated that Paradox walnut hybrids (*Juglans*) and wingnuts (*Pterocarya*) have either a high degree of resistance to, or marked tolerance of, the lesion nematode in the situations where tested.

## LITERATURE CITED

1. WHITEHOUSE, W. E., and JOLEY, L. E. Notes on the growth of Persian walnut propagated on rootstocks of the Chinese wing-nut, *Pterocarya stenoptera*. *Proc. Amer. Soc. Hort. Sci.* 52: 103–106. 1948.

# Effect of Boric Acid Sprays Applied During Bloom Upon the Set of Pear Fruits

By L. P. BATJER and A. H. THOMPSON, *U. S. Department of Agriculture, Wenatchee, Wash.*

FOR no apparent reason certain fruit species or varieties frequently fail to set as many fruits as desirable for satisfactory yields. In the Northwest, Anjou pears bloom heavily but characteristically set relatively light crops. Degman (4) has applied sprays containing different growth regulating chemicals to Anjous during the bloom period but failed to obtain any increase in fruit set. Several investigators (1, 2, 3) have reported that boric acid or borax added to the sugar medium increased both the percentage of pollen germination and the pollen tube growth for certain plant species. Blaha and Schmidt (3) reported that the addition of 0.0005 per cent boron to the culture medium resulted in a much higher germination of cherry and pear pollen, but no increase was obtained with plum and prune pollen. Eaton (5) has presented evidence to indicate that at least one of the functions of boron in plant nutrition is intimately related to the formation of plant hormones. Reports by these investigators serve to indicate the background for initiating experiments to determine the effect of boric acid sprays applied during the bloom period on the set of Anjou pears.

## METHODS

In 1948 two Anjou orchards in the vicinity of Wenatchee, Washington, were selected for experimental treatment. In both orchards four limbs (200 to 300 blossom clusters per limb) located on the south side were selected on each of 10 trees. When 40 to 60 per cent of the blossoms were open, boric acid sprays at concentrations of 5, 25, and 125 ppm of boron were applied to individual limbs on each tree. The fourth limb on each tree served as a control. Fruit set records were obtained on an individual limb basis by counting the blossom clusters prior to treatment and the number of fruits remaining after the June drop.

## RESULTS

The data presented in Table I indicate a consistent increase in fruit set with increase in concentration of boron applied. In both orchards the 125 ppm treatment and in the Griffith orchard the 25 ppm treatment resulted in a significantly greater fruit set than the control.

TABLE I—EFFECT OF BORIC ACID SPRAYS APPLIED DURING THE BLOOM PERIOD ON THE SET OF ANJOU PEARS

| Spray Treatment | Number Fruits Per 100 Blossoming Spurs | |
|---|---|---|
| | Griffith Orchard | Peterson Orchard |
| Control | 20 | 38 |
| 5 ppm Boron | 26 | 47 |
| 25 ppm Boron | 29* | 53 |
| 125 ppm Boron | 32* | 60* |

*Significantly greater than the control at 5 per cent point.

## Discussion

Under the conditions prevailing in this experiment it seems evident that boric acid sprays significantly increased the set of Anjou pears. In speculating on the role of boron in this instance there seem to be at least three possibilities, all of which may be more or less interrelated: (a) stimulation of pollen germination and pollen tube growth; (b) stimulatory effect of the boron on formation of plant auxins during and immediately following the bloom period; (c) correction of an incipient or temporary deficiency of boron.

It is commercial practice in the area where these studies were performed to make soil applications of boric acid at periodic intervals. In 1947 both of the experimental orchards received a soil application of boric acid at the rate of 30 pounds per acre. Although no visible boron deficiency symptoms have ever been observed in these orchards, the decisions to make such applications were based on the fact that occasional boron deficiency has occurred in the general area where the orchards are located. Analysis of fruit and leaves at harvest time (1948) showed the boron content of both tissues well within the luxury range. Whether or not there was an incipient deficiency during the bloom period is a matter of speculation. If boron within the tissue of the pear tree is relatively immobile, a temporary deficiency of this element could possibly have been a limiting factor in fruit set. The spring of 1948 was abnormally cold and wet, a condition that might possibly have restricted the supply of boron to young developing growth provided there was no boron reserve available within the tissues for retranslocation. If this hypothesis is correct, boric acid sprays could hardly be expected to increase the set of fruit in a season more favorable for boron absorption from the soil.

More extensive work is in progress to determine various aspects of response to boric acid sprays covering a wide range of fruit species, varieties, and conditions.

## Literature Cited

1. Ark, P. A. Further studies on walnut blight. *Diamond Walnut News* 31, No. 2: 4. 1949.
2. Berling, V. V. Influence of major and minor elements on pollen germination in plants. *Compt. Rend. (Doklady) Acad. Sci. USSR* 32, No. 6: 439–442. 1941.
3. Blaha, J., and Schmidt, J. The effects of boron on the germination of pollen in fruit trees. *Sbor. Cesk. Akad. Zem.* 14 No. 2: 186–192. 1939.
4. Degman, E. S. Unpublished data. *U. S. Department of Agriculture, Medford, Oregon.*
5. Eaton, Frank M. Interrelations in the effects of boron and indoleacetic acid on plant growth. *Bot. Gaz.* 101: 700–705. 1940.

# Chemical Thinning of Apples at Blossom Time and Up to Four Weeks from Petal Fall[1]

By F. W. Southwick and W. D. Weeks, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

The use of the sodium salt of naphthaleneacetic acid (NaNAA) offers considerable promise as a post-blossom thinning material for apples (2, 3). Experimentally it has been used chiefly at calyx time although some results of later applications have been reported (2). Obviously, from the standpoint of obtaining maximum benefits in fruit size and annual flowering of alternately bearing trees, early thinning is desirable. However, a calyx application of NaNAA may not be any more desirable than a blossom application of a dinitro material in seasons when conditions are unfavorable for fruit set, because it may not be possible to determine accurately whether a thinning problem exists at that time. During the 1948 season the blossom period was cool and wet and it seemed desirable to obtain further information concerning the possibilities of thinning at periods beyond calyx when the extent of fruit set could be more accurately determined before any thinning material was applied.

Two rather fundamental inquiries concerning the use of NaNAA for chemical thinning are why this material causes the abscission of some flowers and young fruits but not others, and when does the increase in the rate of abscission take place following its application? It has been frequently observed in field tests that thinning with NaNAA seemed heavier on the inner, shaded portions of the tree or on low, weak limbs than it is on the more vigorous parts of the tree.

In an effort to obtain more precise information on the above points some preliminary work was initiated. In addition, further work was done comparing blossom treatments of the dinitro DN No. 1 (40 per cent dinitro-ortho-cyclochexylphenol) with calyx and after petal-fall sprays of NaNAA.

## Results

*Influence of NaNAA on the Set of Flower Buds Varying in Vigor:*—Work of Blake *et al* (1) shows that there is a definite positive correlation between the size of a dormant flower bud and its chances of maturing fruit. With Wealthy, for example, dormant flower buds from 0.19 inches (4.8 mm) in diameter and larger set much more heavily than those under that size (1). Nine limbs from three on-year, mature Wealthy trees were selected to determine what influence NaNAA had on the set of spur flower buds of different vigor. On each of these limbs 100 spur flower buds were selected in March and their maximum diameter in millimeters recorded. Each bud was tagged and numbered. The limbs were open pollinated, a row of Cortland being about 60 feet from them. Data presented in Table I show the average set of the blossoming spur buds of various sizes on three limbs, respectively, after a calyx and a 2-week-after-calyx application of NaNAA as compared to unsprayed buds on similar limbs.

[1]Contribution No. 701 of the Massachusetts Agricultural Experiment Station.

TABLE I—THE INFLUENCE OF SODIUM NAPHTHALENEACETATE ON THE SET OF WEALTHY SPUR FLOWER BUDS

| Treatment | No. Limbs | Dormant Flower Buds | | No. Fruits Set | Fruits Per 100 Flowering Buds |
|---|---|---|---|---|---|
| | | Size Groups (Diameter in Mm) | No. in Each Group | | |
| Check | 3 | -4.1 | 28 | 8 | 28.6 |
| | | 4.1-4 7 | 124 | 39 | 31.5 |
| | | 4.8-5 4 | 116 | 50 | 43.1 |
| | | 5.5 + | 32 | 23 | 71.9 |
| NaNAA-20 ppm at calyx | 3 | -4.1 | 28 | 0 | 0.0 |
| | | 4.1-4.7 | 126 | 16 | 12.7 |
| | | 4.8-5.4 | 132 | 30 | 22.7 |
| | | 5.5+ | 16 | 9 | 56.3 |
| NaNAA-40 ppm 2 wks from calyx | 3 | -4.1 | 19 | 0 | 0.0 |
| | | 4.1-4.7 | 131 | 15 | 11.5 |
| | | 4.8-5.4 | 141 | 44 | 31.2 |
| | | 5.5+ | 9 | 5 | 55.5 |

The data indicate that vigor of the spur is an important factor in determining why NaNAA thins some blossom buds to a greater extent than others. Those under 4.7 mm in diameter were thinned to a greater degree than those 4.8 mm and up.

*Effect of NaNAA on Rate of Flower and Young Fruit Abscission:* —In an effort to determine when thinning takes place following applications of NaNAA, eight Golden Delicious trees of uniform vigor were selected. This variety was selected since some unpublished work of Hoffman and Edgerton in 1946 indicated the variety could be thinned long after calyx. Two layers of tobacco cloth were spread under each tree so that all drops could be collected and counted. Two trees were left as controls while an equal number were sprayed at calyx, 2 and 4 weeks after calyx with 15, 30 and 50 ppm of NaNAA, respectively. All drop flowers and fruits were counted (daily when possible) as well as those remaining on the tree at harvest time. Data on yield and size of fruit were collected also. From these data it was possible to calculate the accumulated per cent drop following applications of this material as shown in Fig. 1. Table II includes a tabular summary of the data.

From the data in Fig. 1 and Table II it is apparent that thinning on Golden Delicious in this instance was accomplished with applications of NaNAA as late as 4 weeks from calyx. Because of poor pollination weather, the set was not as heavy as the bloom indicated it might be. In this test the bulk of the drop (about 80 per cent) consisted of unfertilized or partially fertilized flowers which fell by June 8. The trees which received the calyx application commenced to drop small fruits (up to ⅛ inch in diameter) by June 9 and the unsprayed trees 2 days later. For a period of 8 days, from June 8 to 15, the calyx sprayed trees had a noticeably heavier drop than the controls. It was during this period which commenced 12 days from the time of application of NaNAA that the bulk of the thinning influence of the material took place. Another period of increased drop commenced on June 25 and persisted for a few days as far as the trees treated at calyx were concerned. These differences in set appeared to be slight, as shown in Fig.

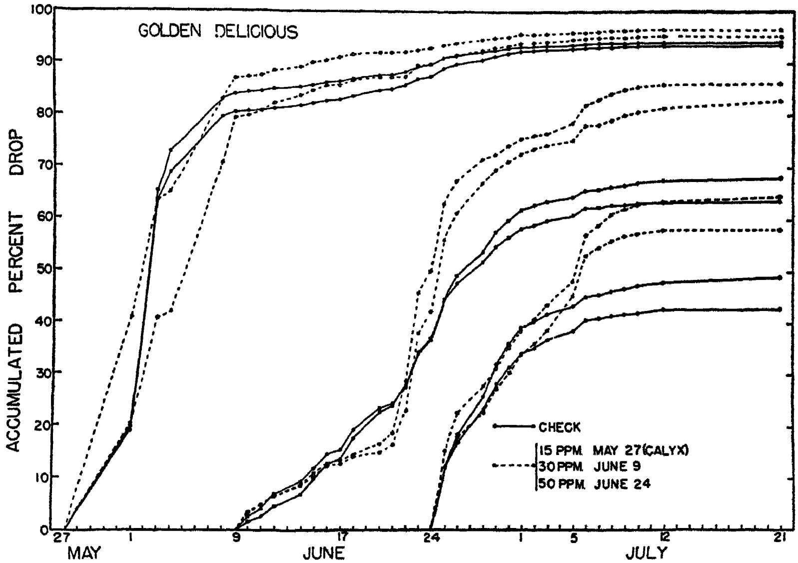



FIG. 1. The accumulated per cent drop from Golden Delicious trees sprayed on May 27, June 9, and June 24 with NaNAA.

1, on a percentage basis (check 6.5 and 6.0; calyx sprayed 3.4 and 4.7), however, it must be remembered that the trees bore up to approximately 49,000 flowers in some cases so that a drop of 1,000 fruits would only amount to approximately 2 per cent of the original flowers. The influence of the calyx treatment on fruit size also indicates that thinning took place.

The application 2 weeks from calyx showed no influence on the per-

TABLE II—THE INFLUENCE OF SODIUM NAPHTHALENEACETATE ON THE DROP OF FLOWERS AND YOUNG FRUITS FROM GOLDEN DELICIOUS APPLE TREES

| Treatment (Per 100 Gals Water) | Tree No. | Total Flowers | Accumulated Per Cent Drop at Time of Spraying | No. Flowers and Young Fruits on Tree at Time of Spraying | No. Fruits Harvested | Per Cent Set From Time of Spraying | Average No. Fruits Per Bu |
|---|---|---|---|---|---|---|---|
| Check | E-5<br>E-7 | 44,853<br>49,465 | 0.0<br>0.0 | 44,853<br>49,465 | 2,925<br>2,981 | 6.5<br>6.0 | 166 |
| NaNAA-15 ppm Calyx—May 27 | E-1<br>E-3 | 42,703<br>34,380 | 0.0<br>0.0 | 42,703<br>34,380 | 1,475<br>1,619 | 3.4<br>4.7 | 123 |
| Check | E-5<br>E-7 | 44,853<br>49,465 | 80.0<br>83.5 | 8,984<br>8,140 | 2,925<br>2,981 | 32.6<br>36.6 | 166 |
| NaNAA-30 ppm June 9 | E-11<br>E-13 | 39,401<br>28,196 | 78.4<br>76.4 | 8,499<br>6,648 | 1,512<br>944 | 17.8<br>14.2 | 133 |
| Check | E-5<br>E-7 | 44,853<br>49,465 | 87.3<br>89.5 | 5,679<br>5,175 | 2,925<br>2,981 | 51.5<br>57.6 | 166 |
| NaNAA-50 ppm June 24 | E-9<br>E-15 | 39,016<br>45,209 | 84.9<br>82.4 | 5,872<br>7,946 | 2,135<br>3,368 | 36.4<br>42.4 | 142 |

centage of drop until June 17. At this time it appears that the treatment resulted in a temporary delay in abscission for a period of 4 days which was immediately followed by a marked increase in drop for a period of 4 to 5 days. In this instance 11 days elapsed from the time of spraying until an increase in fruit drop occurred.

The June 24 application, 50 ppm of NaNAA, resulted in an increased rate of drop which started on July 3, 9 days after the material was applied. The period of an increased rate of abscission lasted for about 3 days. It has yet to be determined whether thinning with this material could be accomplished after the natural June drop is past. Neither the 2- nor the 4-weeks from calyx application resulted in as large fruit size as the calyx application.

None of the treatments on Golden Delicious appeared to cause any permanent type of foliage injury. For several days following each treatment the trees had a wilted appearance, but they seemed to fully recover from this condition.

*Influence of Thinning Materials on Set, Size and Yield of Fruit:*— A comparison of thinning with DN No. 1 and with NaNAA was carried out in a uniform block containing approximately 100 15-year-old Early McIntosh trees interplanted almost tree for tree with McIntosh. On May 10 to 12 temperatures rose to about 80 degrees F in this orchard and the first blossoms commenced to open. However, the weather turned cool and rainy with temperatures only occasionally above 60 degrees F for the next 10 days with some rain on 7 of those 10 days. On May 20 the spur flowers were as near full bloom as could be judged under the circumstances and half of the block was sprayed with DN No. 1, using a speed sprayer. On May 24 all but seven of the remaining trees were sprayed with 20 ppm of NaNAA. At this time petals were still present on some of the flowers originating from lateral and terminal flower buds on the shoots. Table III is a summary of the results taken from seven trees of uniform trunk diameter. The methods of obtaining set and size data were the same as previously discussed (3).

As can be seen from the set and total yield data, the trees sprayed with NaNAA were over thinned. However, the fruit on these trees were of unusually large size and actually produced more fruit 2½ inches and up than the checks hand thinned in early July. From the standpoint of degree of thinning, the DN No. 1 treatment was exceptionally good. The fruit was of good size and these trees definitely out-

TABLE III—The Influence of Some Thinning Materials Applied at Blossom Time and Later on the Set, Yield and Size of Early McIntosh Apples

| Treatment (Per 100 Gals Water) | No. Trees | Average Trunk Circumference (Cm) | Fruits Per 100 Blossoming Clusters | Average Yield (Bu) | | | | Per Cent of Yield + 2¼ Inches |
|---|---|---|---|---|---|---|---|---|
| | | | | -2¼ Inches | 2¼ to 2¾ Inches | 2¾ + Inches | Total | |
| Check (hand thinned) | 7 | 70.5 | 32.6 | 3.0 | 5.6 | 0.0 | 8.6 | 65.4 |
| DN No. 1 1 lb May 20 (full bloom) | 7 | 72.4 | 16.4 | 0.5 | 5.7 | 4.5 | 10.7 | 95.3 |
| NaNAA-20 ppm May 24 (early calyx) | 7 | 70.1 | 3.2 | 0.0 | 1.8 | 4.8 | 6.6 | 100.0 |

yielded the hand thinned controls. However, the fruit on trees receiving DN No. 1 showed more russeting and cracking, and poorer finish than the fruit on the checks or NaNAA treatment.

There was a considerable amount of permanent curling and dwarfing of the spur leaves on those trees which received NaNAA. This injury apparently is apt to be much more prevalent on susceptible varieties at early calyx or calyx than it is a week or two later even though higher concentrations are used later.

Further work was done in other orchards to obtain more information concerning the possibility of thinning apples after calyx as well as at blossom and calyx time. Table IV presents some fruit-set data taken from mature Early McIntosh and McIntosh trees subjected to various chemical thinning treatments. A high pressure sprayer was used to apply these materials.

TABLE IV—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT BLOSSOM TIME AND LATER ON THE SET OF APPLES

| Treatment (Per 100 Gals Water) | No Trees | No. Blossoming Clusters | No. Fruits | Fruits Per 100 Blossoming Clusters |
|---|---|---|---|---|
| *Early McIntosh* | | | | |
| Check | 3 | 756 | 381 | 50.4 |
| DN No. 1—1 lb (full bloom) | 4 | 1,079 | 276 | 25.8 |
| NaNAA—20 ppm (late calyx) | 3 | 887 | 308 | 34.7 |
| NaNAA—50 ppm (3 weeks from calyx) | 3 | 1,042 | 124 | 11.9 |
| *McIntosh* | | | | |
| Check | 4 | 1,002 | 362 | 36.1 |
| NaNAA—10 ppm (calyx) | 4 | 1,284 | 303 | 23.6 |
| NaNAA—15 ppm (calyx) | 4 | 1,167 | 285 | 24.4 |
| NaNAA—15 ppm (2 weeks from calyx) | 4 | 1,299 | 182 | 14.0 |
| NaNAA—20 ppm (2 weeks from calyx) | 4 | 1,301 | 162 | 12.5 |
| NaNAA—40 ppm (4 weeks from calyx) | 4 | 1,336 | 201 | 15.0 |

The data in Table IV show that marked thinning with NaNAA materials may be obtained on these varieties up to at least 3 or 4 weeks after calyx. It was observed on these Early McIntosh that the late calyx and 3 weeks after calyx applications did not produce any appreciable amount of permanent curling and dwarfing of spur leaves. With the McIntosh the calyx applications were definitely more harmful to the foliage than those employed later. The data from McIntosh show that 15 ppm of NaNAA applied 2 weeks after calyx reduced set to a greater extent than the same concentration applied at calyx. The reason for this is not understood. Generally higher concentrations are needed as the interval from blossoming increases.

## LITERATURE CITED

1. BLAKE, M. A., EDGERTON, L. J., and DAVIDSON, O. W. Standards for judging the growth status of apples in New Jersey. *N. J. Agr. Exp. Sta. Bul.* 715. 1945.
2. HOFFMAN, M. B., SOUTHWICK, F. W., and EDGERTON, L. J. A comparison of two types of materials for the chemical thinning of apples. *Proc. Amer. Soc. Hort. Sci.* 49: 37–41. 1947.
3. SOUTHWICK, F. W., HOFFMAN, M. B., and EDGERTON, L. J. Further experiences with the chemical thinning of apples and peaches. *Proc. Amer. Soc. Hort. Sci.* 51: 41–47. 1948.

# Viability of Apple Pollen in Pollen Pellets of Honeybees

By SARDAR SINGH and DAMON BOYNTON, *Cornell University, Ithaca, N. Y.*

THE removal of pollen pellets from the legs of bees is readily accomplished by a pollen trap inserted at the entrance of the colony (4). As Kremer (2) has indicated, pollen collected in this way might be used for commercial pollination operations if there were certainty that it could be held in a viable condition for a reasonable length of time. Since the work of Maurizio (3) and unpublished preliminary studies at Cornell indicated that under some conditions the viability of pellet pollen decreased rapidly, the investigation reported below was undertaken to find out how long pollen collected in this way remained viable.

## PROCEDURE

An 18-year-old Red Delicious tree in the Cornell University orchard at Ithaca, New York was surrounded by a cheese cloth cage on May 9, 1948 when the blossoms were showing pink. On May 10, a colony of bees was placed in the cage, with a pollen trap described by Schaefer and Farrar (4) inserted at the hive entrance. Pollen pellets were collected from bees while at work inside the cage, and from the pollen trap. Pollen pellets were also taken from bees outside the cage, caught as they were collecting from a Red Delicious tree, a McIntosh tree, and a Northern Spy tree.

The viability of the pollen samples was tested in one or both of two ways — by germination on agar media (1.5 per cent agar, 10 per cent sugar) and by determination of the set following hand pollination of flowers on bagged branches of McIntosh, Delicious, and Northern Spy trees, (all varieties were cross-pollinated). Several samples of pollen from blossoms of these varieties were collected by hand and were also tested periodically for viability.

The pellet pollen was placed in thin (not more than $^{1}/_{16}$-inch thick) layers in open-mouthed ¾ by 3 inch vials and held prior to germination in one of three ways: (a) at room temperature (designated OT); (b) in a desiccator containing anhydrous calcium chloride which was placed at 32 degrees F after 3 hours (designated DR); and (c) in a desiccator containing anhydrous calcium chloride cooled by ice during the first 3 hours and then transferred to 32 degrees F (designated DIR).

The set counts for the bagged hand-pollinated branches were made on June 8 after the blossom drop, but prior to the "June drop", since physiological competition factors are apt to complicate the interpretation of set data taken after the June drop (1).

## RESULTS

The results are summarized in Tables II to V.

The bloom period occurred during rather unfavorable weather, with only short periods warm enough for bee activity and pollen tube growth (Table I). No freezing temperatures occurred during the

TABLE I—WEATHER AND PHENOLOGICAL DATA DURING THE EXPERIMENT

| Date May 1948 | Temperature Max | Temperature Min | Weather | Remarks |
|---|---|---|---|---|
| 11 | 80 | 50 | Clear, sunny | McIntosh full bloom, good bee flight |
| 12 | 58 | 52 | Rain, cold, cloudy | |
| 13 | 55 | 52 | Rain all day | |
| 14 | 53 | 50 | Rain all day | |
| 15 | 67 | 45 | Forenoon cold—afternoon sunny | McIntosh and Delicious bloom fair, bee flight fair |
| 16 | 65 | 52 | Rain till noon | McIntosh bloom waning, meager bee flight |
| 17 | 67 | 54 | Intermittent showers and thick clouds passing | Meager bee flight |
| 18 | 52 | 48 | Rain all day | |
| 19 | 56 | 39 | Sunny but too cold | Meager bee flight |
| 20 | 58 | 34 | Sky overcast with clouds | Meager bee flight |
| 21 | 66 | 46 | Forenoon clear, afternoon showers | Meager bee flight |
| 22 | 57 | 42 | Cold, cloudy, foggy, and drizzling | Meager bee flight |
| 23 | 59 | 47 | Rainy and cold | |
| 24 | 71 | 48 | Forenoon cloudy and cold, afternoon warmer | A little bloom left, meager bee flight |
| 25 | 68 | 45 | Sunny, cool breeze | A little bloom left, meager bee flight |

experimental period, although 34 degrees F was reached on May 20 and it was generally cool and cloudy.

The pollen from hand-collected blossoms was initially viable to a high degree and remained so after 1 to 9 days storage in open vials at room temperature (Table II).

TABLE II—GERMINATION OF POLLEN FROM BLOSSOM SAMPLES COLLECTED BY HAND AND STORED AT ROOM TEMPERATURE IN OPEN VIALS

| Sample No. | Variety | Tree | Number of Days Storage 1 | 5 | 9 |
|---|---|---|---|---|---|
| | | | Relative Germination After Storage* | | |
| 1 | Red Delicious | Caged | | | f |
| 2 | | 43-7-39 | vg | vg | |
| 3 | | 43-7-39 | | | g |
| 4 | McIntosh | 43-1-25 | vg | | |
| 5 | | 43-1-25 | | | f |
| 6 | Northern Spy | 43-3-21 | g | | |

*f—15.1 to 30 per cent.
g—45.1 to 60 per cent.
vg—More than 60 per cent.

The data on germination of pellet pollen from the caged Red Delicious tree is summarized in Table III. Regardless of variation in initial viability, and in storage treatment, there was a continuous decline in germination of practically all pollen pellet samples, a decline which was most rapid during the first 5 hours of storage, but was evident during the first 2 days. Thus, at 0 hours, 6 (25 per cent) of the 24 tests germinated from poor to nil; in the 1 to 5 hours storage period, 30 (62 per cent) of the 48 tests germinated from poor to nil; in the 6 to 50 hours storage period, 37 (74 per cent) of the 50 tests germinated from poor to nil; and in the subsequent storage period, 10 (91 per cent) of the 11 tests were in that germination group. Most of the decline in viability appeared to take place during the first 2 hours of storage. This may have significance in explaining the variation in initial viability of hand-collected pellet pollen, since there

would be considerable variation in the period of time taken by a bee to collect a pellet. It would also explain the greater variation in initial viability of pellet pollen taken from the trap after a lapse of time. Storage of the pollen pellets in a desiccator and under refrigeration did not show a consistent beneficial effect on viability, although in some instances, there was apparent lengthening of the time during which germination was satisfactory. Delicious pollen collected from the trap on May 24 and 25 seemed to be initially low in germination. This may have been partly due to the fact that the pollen was collected from the last remaining blossoms.

The data in Table III are corroborated by germination data in

TABLE III—Germination of Pellet Pollen from the Caged Red Delicious Tree

| Sample No. | Collection | | | Storage | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Method | May 1948 | Hour | Method | Hours Prior to Germination Test (Relative Germination)† | | | | | | | | | | | |
| | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6–10 | 11–25 | 26–50 | 51–75 | 76–100 | 101–130 |
| 7 | Hand | 15 | 1:30 | OT* | | | | | | | vp | | | | | |
| 8 | | 15 | 3:20 | OT | | | | | | O | | | | | | |
| 9 | | 15 | 5:30 | OT | | | p | | | | | | | | | |
| 10 | | 16 | 3:50 | OT | f | p | | O | | | | | | | | |
| 11 | | 16 | 4:00 | OT | f | vp | O | | | | | | | | | |
| 12 | | 17 | 1:30 | OT | p | p | p | O | | | | | | | | |
| 13 | | 19 | 4:10 | OT | vg | vg | | | | g | vf | f | vp | | | |
| 14 | | 19 | 4:45 | OT | g | | | | f | | vp | | | | | |
| 15 | | 20 | 12:30 | DR | vg | | | | g | vf | f | f | vf | f | O | |
| 16 | | 20 | 12:40 | DR | vg | | | | vg | vg | g | vf | f | p | p | O |
| 17 | | 22 | 2:15 | DIR | | | g | | | | f | f | p | O | | |
| 18 | | 22 | 2:25 | DIR | | | f | | | | vp | vp | vp | | | |
| 19 | | 22 | 2:45 | DIR | | | vg | | | | p | f | p | O | | |
| 20 | | 24 | 2:40 | OT | vf | | | | | | O | O | | | | |
| 20 | | 24 | 2:40 | DIR | vf | | | | | | vp | p | | | | |
| 21 | | 25 | 2:50 | DIR | f | p | | p | | | p | | | | | |
| 22 | | 25 | 3:10 | OT | f | p | | vp | | | O | | | | | |
| 22 | | 25 | 3:10 | DIR | f | p | | p | | | vp | | | | | |
| | Trap | | | | | | | | | | | | | | | |
| 23 | | 15 | 2:40 | OT | | | | | | | O | | | | | |
| 24 | | 15 | 2:40–5:45 | OT | | | O | | | | | | | | | |
| 25 | | 16 | 3:58 | OT | vf | g | | O | | O | | | | | | |
| 26 | | 17 | 1:30 | OT | p | vp | vp | p | | O | | | | | | |
| 27 | | 17 | 1:30–5:00 | OT | | | | | | | O | | | | | |
| 28 | | 19 | 12:20 | OT | vg | | | vf | | | p | | | | | |
| 29 | | 19 | 4:00 | OT | | vf | | vf | | | vp | O | | | | |
| 30 | | 19 | 5:00 | OT | vf | | | | vp | vp | | | | | | |
| 31 | | 20 | 12:20 | DR | g | | | g | | vf | f | f | p | p | p | p |
| 32 | | 20 | 12:20–1:20 | DR | g | | | p | | p | p | vp | vp | | | |
| 33 | | 22 | 2:00 | DIR | | | vp | | | | O | | | | | |
| 34 | | 22 | 2:50 | DIR | | vf | | | | | p | p | vp | O | | |
| 35 | | 24 | 2:25 | DIR | O | | | | | | O | | | | | |
| 36 | | 24 | 2:25–3:55 | OT | p | | | | | | O | O | | | | |
| 36 | | 24 | 2:25–3:55 | DIR | p | | | | | | vp | O | | | | |
| 37 | | 25 | 2:30 | OT | f | | O | | O | | O | | | | | |
| 37 | | 25 | 2:30 | DIR | f | | | | f | | p | | | | | |
| 38 | | 25 | 2:30–3:30 | DIR | p | | p | | | | vp | | | | | |

*OT—ordinary temperature; DR—pollen in vial placed immediately in desiccator and after 3 hours the desiccator was placed in refrigerator at 32 degrees F in the laboratory; DIR—pollen in vial placed immediately in dessicator which was in turn placed in ice for 3 hours and later transferred to refrigerator at 32 degrees F in the laboratory.

†O—no germination
vp—germination 5 per cent
p—5.1 to 15 per cent
f—15.1 to 30 per cent
vf—31.1 to 45 per cent
g—45.1 to 60 per cent
vg—more than 60 per cent

Table IV on pellets from bees caught on uncaged Delicious, McIntosh, and Northern Spy trees, and by data on set of fruit in Table V on bagged branches hand-pollinated by pellet pollen after different storage periods.

TABLE IV—GERMINATION OF HAND-COLLECTED PELLET POLLEN FROM BEES CAUGHT ON UNCAGED RED DELICIOUS, McINTOSH, AND NORTHERN SPY TREES

| Sample | Collection | | | Storage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Hours Prior to Germination Test (Relative Germination) | | | | | | | | | |
| | May 1948 | Hour | Method | 0 | 1 | 2 | 3 | 4 | 5 | 6–10 | 11–25 | 26–50 | 51–75 |
| | | | | *Red Delicious Tree No. 43–7–39* | | | | | | | | | |
| 39 | 15 | 3:30 | OT* | | | | | | vp | | | | |
| 40 | 16 | 3:40 | OT | vg | g | | vg | | f | f | f | vp | |
| 41 | 17 | 2:45 | OT | vg | g | g | f | | | p | p | vp | |
| 42 | 20 | 2:00 | DR | vg | | | g | | p | f | f | vf | f† |
| 43 | 24 | 2:55 | OT | vg | | | | | | vp | O | | |
| 43 | 24 | 2:55 | DIR | vg | | | | | | vf | p | | |
| 44 | 24 | 3:25 | OT | f | | | | | | O | | | |
| 44 | 24 | 3:25 | DIR | f | | | | | | O | | | |
| | | | | *McIntosh Tree No. 43–1–25* | | | | | | | | | |
| 45 | 11 | 5:20 | OT | | | | p‡ | | | | | | |
| 46 | 11 | 5:30 | OT | | | | | | | O‡ | O | | |
| 47 | 15 | 4:50 | OT | | | | vp | | | O | | | |
| 48 | 15 | 6:10 | OT | | | p | | | O | | | | |
| 49 | 16 | 4:25 | OT | f | | | | | | | | | |
| | | | | *Northern Spy Tree No. 43–3–23* | | | | | | | | | |
| 50 | 15 | 6:20 | OT | | p | | | O | | | | | |
| 51 | 17 | 2:55 | OT | g | g | vf | g | | | vp | O | | |
| 52 | 25 | 3:45 | OT | p | | p | | | | vp | | | |
| 52 | 25 | 3:45 | DIR | p | | p | | | | p | | | |

*See footnote Table III for explanation of symbols.
†Samples exhausted.
‡Sample taken just following flotation sulfur spray, and pellets had yellow green color.

TABLE V—EARLY SET OF FRUIT ON BAGGED BRANCHES THAT WERE HAND-POLLINATED WITH VARIOUS POLLEN MATERIALS

| No. | Pollen Variety | Pollen Type | Reference No. in Tables II, III, and IV | Age (Hours) | Mother Variety | No. Clusters | No. Fruits Set on June 8 |
|---|---|---|---|---|---|---|---|
| 1 | Red Delicious | Natural | 2 | 120 | McIntosh | 70 | 28 |
| 2 | Red Delicious | Outside Bee pellet Hand collected | 39 | ½ | McIntosh | 27 | 9 |
| 3 | Red Delicious | Cage bee Pellet Hand collected | 44 | ½ | McIntosh | 27 | 7 |
| 4 | Red Delicious | | 44 | 1 | McIntosh | 63 | 29 |
| 5 | Red Delicious | | 7 | ½ | McIntosh | 40 | 13 |
| 6 | Red Delicious | Outside Bee pellet Hand collected | 41 | 1 | Northern Spy | 24 | 12 |
| 7 | Red Delicious | Cage tray | 23 | ½ | McIntosh | 50 | 5 |
| 8 | Red Delicious | Cage tray | 23 | ⅔ | McIntosh | 52 | 13 |
| 9 | Red Delicious | Cage tray | 23 | 1 | McIntosh | 97 | 16 |
| 10 | Red Delicious | Cage tray | 26 | ½ | Northern Spy | 11 | 24 |
| 11 | Red Delicious | Cage tray | 26 | 1 | Northern Spy | 25 | 21 |
| 12 | Red Delicious | Cage tray | 26 | 2 | Northern Spy | 18 | 11 |
| 13 | Red Delicious | Cage tray | 26 | 4 | Northern Spy | 13 | 4 |
| 14 | Red Delicious | Cage tray | 26 | 52 | Northern Spy | 10 | Nil |
| 15 | Red Delicious | Cage tray | 26 | 52 | Northern Spy | 23 | Nil |
| 16 | Red Delicious | Cage tray | 31 | 31 | Northern Spy | 24 | Nil |
| 17 | Red Delicious | Cage tray | 31 | 31 | Northern Spy | 11 | Nil |
| 18 | Red Delicious | Cage tray | 32 | 30 | Northern Spy | 23 | Nil |
| 19 | McIntosh | Natural | 4 | 120 | Delicious | 60 | 27 |
| 20 | McIntosh | Outside Bee pellet Hand collected | 47 | 1 | Delicious | 32 | 1 |
| 21 | McIntosh | | 45 | 96 | Delicious | 33 | Nil |
| 22 | Northern Spy | | 51 | 1 | Delicious | 35 | Nil |

would be considerable variation in the period of time taken by a bee to collect a pellet. It would also explain the greater variation in initial viability of pellet pollen taken from the trap after a lapse of time. Storage of the pollen pellets in a desiccator and under refrigeration did not show a consistent beneficial effect on viability, although in some instances, there was apparent lengthening of the time during which germination was satisfactory. Delicious pollen collected from the trap on May 24 and 25 seemed to be initially low in germination. This may have been partly due to the fact that the pollen was collected from the last remaining blossoms.

The data in Table III are corroborated by germination data in

TABLE III—Germination of Pellet Pollen from the Caged Red Delicious Tree

| Sample No. | Collection | | | Storage | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Hours Prior to Germination Test (Relative Germination)† | | | | | | | | | | | |
| | Method | May 1948 | Hour | Method | 0 | 1 | 2 | 3 | 4 | 5 | 6–10 | 11–25 | 26–50 | 51–75 | 76–100 | 101–130 |
| 7 | Hand | 15 | 1:30 | OT* | | | | | | | vp | | | | | |
| 8 | | 15 | 3:20 | OT | | | | | | O | | | | | | |
| 9 | | 15 | 5:30 | OT | | | p | | | | | | | | | |
| 10 | | 16 | 3:50 | OT | f | p | | O | | | | | | | | |
| 11 | | 16 | 4:00 | OT | f | vp | O | | | | | | | | | |
| 12 | | 17 | 1:30 | OT | p | p | p | O | | | | | | | | |
| 13 | | 19 | 4:10 | OT | vg | vg | | | | g | vf | f | vp | | | |
| 14 | | 19 | 4:45 | OT | g | | | | f | | vp | | | | | |
| 15 | | 20 | 12:30 | DR | vg | | | | g | vf | f | f | vf | f | O | |
| 16 | | 20 | 12:40 | DR | vg | | | | vg | vg | g | vf | f | p | p | O |
| 17 | | 22 | 2:15 | DIR | | | g | | | | f | f | p | O | | |
| 18 | | 22 | 2:25 | DIR | | | f | | | | vp | vp | vp | | | |
| 19 | | 22 | 2:45 | DIR | | | vg | | | | p | f | p | O | | |
| 20 | | 24 | 2:40 | OT | vf | | | | | | O | O | | | | |
| 20 | | 24 | 2:40 | DIR | vf | | | | | | vp | p | | | | |
| 21 | | 25 | 2:50 | DIR | f | p | | p | | | p | | | | | |
| 22 | | 25 | 3:10 | OT | f | p | | vp | | | O | | | | | |
| 22 | | 25 | 3:10 | DIR | f | p | | p | | | vp | | | | | |
| | Trap | | | | | | | | | | | | | | | |
| 23 | | 15 | 2:40 | OT | | | | | | | O | | | | | |
| 24 | | 15 | 2:40–5:45 | OT | | | O | | | | | | | | | |
| 25 | | 16 | 3:58 | OT | vf | g | | O | | O | | | | | | |
| 26 | | 17 | 1:30 | OT | p | vp | vp | p | | O | | | | | | |
| 27 | | 17 | 1:30–5:00 | OT | | | | | | | O | | | | | |
| 28 | | 19 | 12:20 | OT | vg | | | vf | | | p | | | | | |
| 29 | | 19 | 4:00 | OT | | vf | | vf | | | vp | O | | | | |
| 30 | | 19 | 5:00 | OT | vf | | | | vp | vp | | | | | | |
| 31 | | 20 | 12:20 | DR | g | | | g | | vf | f | f | p | p | p | p |
| 32 | | 20 | 12:20–1:20 | DR | g | | | p | | p | p | vp | vp | | | |
| 33 | | 22 | 2:00 | DIR | | | vp | | | | O | | | | | |
| 34 | | 22 | 2:50 | DIR | | vf | | | | | p | p | vp | O | | |
| 35 | | 24 | 2:25 | DIR | O | | | | | | O | | | | | |
| 36 | | 24 | 2:25–3:55 | OT | p | | | | | | O | O | | | | |
| 36 | | 24 | 2:25–3:55 | DIR | p | | | | | | vp | O | | | | |
| 37 | | 25 | 2:30 | OT | f | | O | | O | | O | | | | | |
| 37 | | 25 | 2:30 | DIR | f | | | | f | | p | | | | | |
| 38 | | 25 | 2:30–3:30 | DIR | p | | p | | | | vp | | | | | |

*OT—ordinary temperature; DR—pollen in vial placed immediately in desiccator and after 3 hours the desiccator was placed in refrigerator at 32 degrees F in the laboratory; DIR—pollen in vial placed immediately in dessicator which was in turn placed in ice for 3 hours and later transferred to refrigerator at 32 degrees F in the laboratory.

†O—no germination
vp—germination 5 per cent
p—5.1 to 15 per cent
f—15.1 to 30 per cent
vf—31.1 to 45 per cent
g—45.1 to 60 per cent
vg—more than 60 per cent

Table IV on pellets from bees caught on uncaged Delicious, McIntosh, and Northern Spy trees, and by data on set of fruit in Table V on bagged branches hand-pollinated by pellet pollen after different storage periods.

TABLE IV—GERMINATION OF HAND-COLLECTED PELLET POLLEN FROM BEES CAUGHT ON UNCAGED RED DELICIOUS, MCINTOSH, AND NORTHERN SPY TREES

| Sample | Collection | | | Storage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 1948 | Hour | Method | Hours Prior to Germination Test (Relative Germination) | | | | | | | | | |
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6–10 | 11–25 | 26–50 | 51–75 |
| | | | | *Red Delicious Tree No. 43-7-39* | | | | | | | | | |
| 39 | 15 | 3:30 | OT* | | | | | | vp | | | | |
| 40 | 16 | 3:40 | OT | vg | g | | vg | | f | f | f | vp | |
| 41 | 17 | 2:45 | OT | vg | g | g | f | | | p | p | vp | |
| 42 | 20 | 2:00 | DR | vg | | | g | | p | f | f | vf | f† |
| 43 | 24 | 2:55 | OT | vg | | | | | | vp | O | | |
| 43 | 24 | 2:55 | DIR | vg | | | | | | vf | p | | |
| 44 | 24 | 3:25 | OT | f | | | | | | O | | | |
| 44 | 24 | 3:25 | DIR | f | | | | | | O | | | |
| | | | | *McIntosh Tree No. 43-1-25* | | | | | | | | | |
| 45 | 11 | 5:20 | OT | | | | p‡ | | | | | | |
| 46 | 11 | 5:30 | OT | | | | | | | O‡ | O | | |
| 47 | 15 | 4:50 | OT | | | | vp | | | O | | | |
| 48 | 15 | 6:10 | OT | | | p | | | O | | | | |
| 49 | 16 | 4:25 | OT | f | | | | | | | | | |
| | | | | *Northern Spy Tree No. 43-3-23* | | | | | | | | | |
| 50 | 15 | 6:20 | OT | | p | | | O | | | | | |
| 51 | 17 | 2:55 | OT | g | g | vf | g | | | vp | O | | |
| 52 | 25 | 3:45 | OT | p | | p | | | | vp | | | |
| 52 | 25 | 3:45 | DIR | p | | p | | | | p | | | |

*See footnote Table III for explanation of symbols.
†Samples exhausted.
‡Sample taken just following flotation sulfur spray, and pellets had yellow green color.

TABLE V—EARLY SET OF FRUIT ON BAGGED BRANCHES THAT WERE HAND-POLLINATED WITH VARIOUS POLLEN MATERIALS

| No. | Pollen Variety | Pollen Type | Reference No. in Tables II, III, and IV | Age (Hours) | Mother Variety | No. Clusters | No. Fruits Set on June 8 |
|---|---|---|---|---|---|---|---|
| 1 | Red Delicious | Natural | 2 | 120 | McIntosh | 70 | 28 |
| 2 | Red Delicious | Outside Bee pellet Hand collected | 39 | ½ | McIntosh | 27 | 9 |
| 3 | Red Delicious | Cage bee | 44 | ½ | McIntosh | 27 | 7 |
| 4 | Red Delicious | Pellet | 44 | 1 | McIntosh | 63 | 29 |
| 5 | Red Delicious | Hand collected | 7 | ½ | McIntosh | 40 | 13 |
| 6 | Red Delicious | Outside Bee pellet Hand collected | 41 | 1 | Northern Spy | 24 | 12 |
| 7 | Red Delicious | Cage tray | 23 | ½ | McIntosh | 50 | 5 |
| 8 | Red Delicious | Cage tray | 23 | ⅜ | McIntosh | 52 | 13 |
| 9 | Red Delicious | Cage tray | 23 | 1 | McIntosh | 97 | 16 |
| 10 | Red Delicious | Cage tray | 26 | ½ | Northern Spy | 11 | 24 |
| 11 | Red Delicious | Cage tray | 26 | 1 | Northern Spy | 25 | 21 |
| 12 | Red Delicious | Cage tray | 26 | 2 | Northern Spy | 18 | 11 |
| 13 | Red Delicious | Cage tray | 26 | 4 | Northern Spy | 13 | 4 |
| 14 | Red Delicious | Cage tray | 26 | 52 | Northern Spy | 10 | Nil |
| 15 | Red Delicious | Cage tray | 26 | 52 | Northern Spy | 23 | Nil |
| 16 | Red Delicious | Cage tray | 31 | 31 | Northern Spy | 24 | Nil |
| 17 | Red Delicious | Cage tray | 31 | 31 | Northern Spy | 11 | Nil |
| 18 | Red Delicious | Cage tray | 32 | 30 | Northern Spy | 23 | Nil |
| 19 | McIntosh | Natural | 4 | 120 | Delicious | 60 | 27 |
| 20 | McIntosh | Outside | 47 | 1 | Delicious | 32 | 1 |
| 21 | McIntosh | Bee pellet | 45 | 96 | Delicious | 33 | Nil |
| 22 | Northern Spy | Hand collected | 51 | 1 | Delicious | 35 | Nil |

## Summary

These studies indicate that there is rapid decrease in the viability of pellet pollen, and in its ability to cause fruit set when it is held in pellet form in open vials. If pollen collected from pollen traps inserted at the entrance of bee colonies is to be used for commercial pollination work, it seems necessary to remove the pellets from the traps after short time intervals, and to devise special treatment of the pellets to eliminate the decrease in viability.


## Literature Cited


1. Hough, L. F. The pollen value of 134 apple varieties as determined by germination tests and field trials. *Proc. Amer. Soc. Hort. Sci.* 37: 133–136. 1939.
2. Kremer, J. C. Traps for collection and distribution of pollen in orchards. *Mich. State Col. Dept. of Hort., Mimeo. Circular.* 1948.
3. Maurizio, Anna. Wie Lange bliebt der pollen in den bienenwaben Keimfahlig? Verhand. Sweizerischen Naturwforsch. *Gessellschaft.* 124 Jahresversammlung: 128–129. 1944.
4. Schaefer, C. W., and Farrar, C. L. The use of pollen traps and pollen supplements in developing honeybee colonies. *U. S. D. A. Bur. Ent. Plant. Quar. "E" Series* 531: 7. (Processed). 1941.

# Germination Tests of the Viability of Apple Pollen Gathered in Pellets[1]

By J. C. Kremer, *Michigan State College, East Lansing, Mich.*

Traps for collecting and distributing pollen have recently been introduced as aids to fruit set in Michigan orchards (2). These traps present a new method of distributing pollen in blocks of single varieties which set fruit with difficulty.

The method utilizes the pollen pellets gathered by the bee in place of the more tedious and expensive process of gathering and applying the pollen by hand. Essentially, the procedure is as follows: when the bee returns from its trip to the orchard, the pollen pellets are removed from its legs as it passes through a perforated screen at the entrance to the hive. The pollen, in pellet form, is unsuitable for redistribution by the bee, and hence it is reduced to a fluffy, free-flowing, dustlike mixture by the addition of a diluent (Lycopodium spores) and by rubbing gently or massaging the mixture with the palms of the hands until the pollen pellets or small clumps are broken up. Being dry, the Lycopodium spores prevent the moist pollen grains from adhering to each other and convert the pollen to a suitable form for redistribution. As the bee leaves the hive to return to the orchard, it is forced to pass through the dust-like mixture in the distributing trap. The action of the wings when the bee leaves the hive disturbs the mixture considerably, causing the pollen to be evenly distributed over the body of the bee.

The viability of the pollen pellets gathered and used in this manner may have been influenced by various adverse factors that would affect its usefulness for pollination purposes. For example, the fact that the pollen was gathered by the honeybee rather than by human hands has led to the supposition that the viability of the pollen has in some way been affected and that its usefulness for pollination purposes has been inhibited. Casteel (1) refers to the addition of nectar in the process of gathering and formation of the pollen pellet. Fruit pollen, being waxy and sticky, adheres quite readily to the body hairs of the bee and is transferred quite rapidly to pellet form on the rear legs. It would be reasonably to surmise that if nectar were added at this stage in appreciable amounts, the bee would also be able to gather wind-blown or dry pollen — which it is unable to do with any degree of success. Overley and O'Neill (3) mention the findings of Bullock of the Tree Fruit Branch Experiment Station of Washington, who reports 97 per cent germination in 10 per cent sugar solution within 24 hours and no germination after 14 days. These results are in partial agreement with the findings of the author as to the tolerance of pollen pellets to sugar solutions and their potential viability. No mention was made, however, as to the habits of the bee and the circumstances under which the pollen was gathered, or any adverse conditions that might cause variation in viability and germination of the grains within a pellet. The

[1]Journal article No. 1029 (n.s.) of the Michigan Agricultural Experiment Station.

percentage of germination of a number of samples taken from a single pellet may vary as much as 100 per cent.

A set of fruit in orchards planted to a single variety is usually obtained by hand pollination, or by the use of bouquets of suitable cross-pollinating varieties. In either case, the pollen is presumably fresh, or nearly so, and has a high percentage viability at the time of application. Adverse climatic conditions may lower the percentage germination if the blossoms from which the pollen is obtained are one or more days old or have been subjected to unfavorable storage or climatic conditions.

Pollen is a necessary ingredient for brood-rearing in the hive and ample quantities are a necessity. Inclement weather may cause cessation of bee activity at any time, leaving the pollen available but ungathered. Consumption of pollen supplies continues within the hive, however, and eventually causes a depletion of stores. Flight activity may be resumed before or after dehiscence occurs. As a result of the haste of the bees to replenish supplies in the hive, pollen of all ages may be included in a single pellet. As the bee may visit many varieties before a pollen pellet is completed, varietal differences in vigor and in viability may occur. Also, pollen from varieties having an irregular chromosome arrangement, such as the triploids, may be present. Too long an exposure of the pellets in the collection trap to direct sunlight, hot drying winds, or excess moisture may cause rapid deterioration.

In view of the many variables possibly affecting the germinability of pollen pellets, a few tests providing an indication as to the loss of viability at fluctuating room temperatures were felt desirable. This investigation provides a partial report of results obtained during the spring of 1948.

## Germination Procedure and Methods of Testing

The pollen for these tests was gathered late in the season, hence a wide selection of varieties was not available. Several of the adverse factors previously mentioned as affecting viability were operative, namely, unseasonably high temperatures, hot drying winds, strong sunlight, and a lack of cold storage facilities for 24 hours after the pollen was obtained. Spy and Wealthy were the only varieties in full bloom, with other earlier varieties in the last stages of bloom. Bees were active on all varieties regardless of the condition of the pollen.

Fifteen pollen collecting traps were placed at the entrances of colonies in these areas and yielded over a quart of pollen pellets during a 24-hour period, or a sufficient amount to insure a sample representative of all stages of bloom. The pellets were collected twice during this period and stored therefore at 45 degrees F in a standard home refrigerator, using a glass fruit jar with the lid unfastened. Four days elapsed before germination tests were made.

To obtain a fair average of the possible fresh and old pollen grains in the pellet, a small portion of three different pellets was placed on a slide in a media of 10 per cent sugar and 300 ppm boric acid solution. Six slides thus prepared represented 18 pellets for daily germination counts. Constant germination temperatures were not maintained, but

TABLE I—VARIATIONS IN VIABILITY OF APPLE POLLEN FROM DIFFERENT POLLEN PELLETS GATHERED ON THE SAME DAY AND TESTED AT INTERVALS FROM 5 TO 26 DAYS LATER

| Sample No. | Age of Pollen (Days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 Per Cent | 6 Per Cent | 7 Per Cent | 8 Per Cent | 9 Per Cent | 11 Per Cent | 12 Per Cent | 19 Per Cent | 25 Per Cent | 26 Per Cent |
| 1 | 68 | 83 | 87 | 39 | 42 | 42 | 40 | 12 | 2 | 0 |
| 2 | 82 | 47 | 97 | 24 | 58 | 44 | 28 | 0 | 0 | 0 |
| 3 | 98 | 92 | 89 | 14 | 62 | 43 | 38 | 2 | 0 | 3 |
| 4 | 49 | 68 | 96 | 67 | 70 | 28 | 29 | 3 | 1 | 2 |
| 5 | 63 | 78 | 86 | 50 | 68 | 33 | 22 | 7 | 4 | 6 |
| 6 | 42 | 71 | 96 | 32 | 52 | 48 | 37 | 12 | 4 | 0 |
| 7 | 40 | 42 | 100 | 36 | 67 | 38 | 35 | 6 | 2 | 0 |
| 8 | 92 | 38 | 90 | 58 | 58 | 49 | 34 | 1 | 7 | 2 |
| 9 | 96 | 44 | 50 | 23 | 46 | 31 | 41 | 6 | 2 | 5 |
| 10 | 24 | 97 | 99 | 19 | 28 | 40 | 34 | 8 | 6 | 3 |
| 11 | 30 | 88 | 88 | 42 | 59 | 26 | 44 | 48 | 0 | 0 |
| 12 | 18 | 77 | 100 | 62 | 55 | 29 | 29 | 0 | 4 | 1 |
| 13 | 72 | 78 | 84 | 28 | 72 | 22 | 34 | 9 | 1 | 4 |
| 14 | 35 | 81 | 95 | 41 | 50 | 39 | 34 | 2 | 6 | 2 |
| 15 | 62 | 42 | 100 | 35 | 68 | 26 | 39 | 10 | 7 | 0 |
| 16 | 61 | 97 | 77 | 51 | 38 | 46 | 40 | 5 | 0 | 2 |
| 17 | 78 | 93 | 100 | 26 | 69 | 38 | 38 | 3 | 4 | 4 |
| 18 | 80 | 44 | 86 | 37 | 64 | 44 | 34 | 10 | 4 | 2 |
| Average | 60 | 70 | 90 | 38 | 57 | 37 | 35 | 8 | 3 | 2 |

were allowed to fluctuate at ordinary room temperature varying from 60 to 80 degrees F. Pollen pellets were selected for uniformity of color representing true apple pollen, since foreign pollen pellets of other species are usually present. Pellets of wild mustard *(Barbarea vulgaris)* were the most common foreign pollen, being similar in color but easily distinguished by its higher yellow color. It can also be detected under the microscope in direct comparison with apple pollen. A wild field binocular microscope with 15x eye-pieces and 7.5x objectives made possible a ½ inch field of good distinction of several hundred pollen grains without changing the field. Percentages were based on germinated and non-germinated grains showing tube growth of not more than two or three diameters of the pollen grain. Any less vigorous grains germinating after counts were made would not appreciably alter the percentage figures but would result in confusion due to overlapping of the pollen tubes.

## RESULTS AND CONCLUSIONS

The data tabulated in Fig. 1 show considerable variation from day to day and rapid loss of viability after a 2-week storage period, but only partial viability after 26 days. The lower percentages of viability of the 5- and 6-day-old pollen as compared with the higher percentages for the 7-day and the 8- to 9-day-old pollen show the importance both of the conditions existant at the time of collection and of the random selection of pellets from among so many thousand available. The percentages could easily have been either higher or lower had the viability of the 18 samples averaged either way when the selection was made. An example of this variability is the average of 48 per cent viability for one sample of 19-day-old pollen and a combined average of 8 per cent samples. It is felt that the results here reported are representative

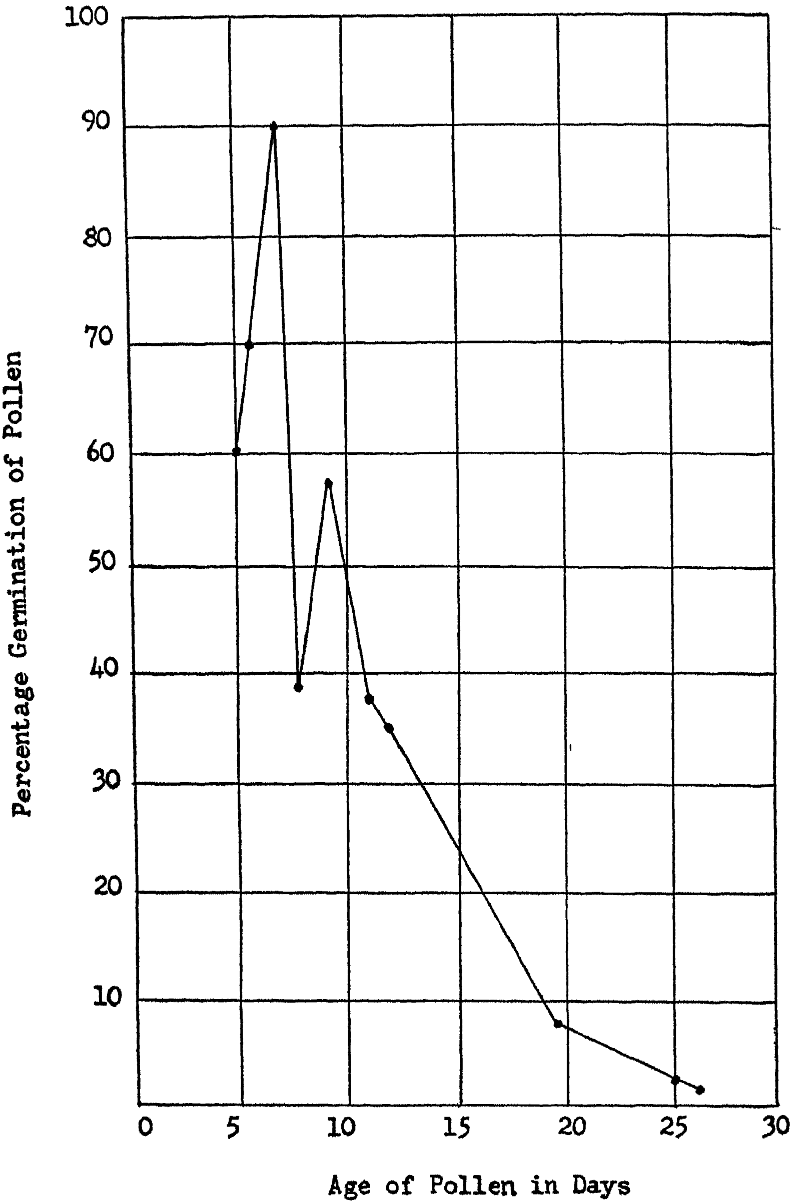



FIG. 1. Influence of age on germinability of pollen pellets stored at 45 degrees F.

of those which might be secured by commercial growers in routine orchard practices. Had the pellets been obtained under more favorable circumstances, and had the best of technical facilities and methods been used, the viability of the pollen would more than likely have been higher and might possibly have extended another week. When such large amounts of pollen are available and used in the distributing traps during the blooming season, any reasonably high percentage of viability such as that obtained over a period of 2 weeks should provide ample amounts of viable pollen between gathering and application.

It would appear, then, that pollen pellets gathered and used for pollination purposes are not materially affected by the addition of nectar that may have been added during the gathering process, and that the additional use of sugar syrup as a germination media does not inhibit pollen tube growth.

## Literature Cited

1. Casteel, D. B. Behavior of the honeybee in collecting pollen. *Bur. Ent. Bul.* 121. 1912.
2. Kremer, J. C. Traps for the collection and distribution of pollen. *Mich. Agr. Exp. Sta. Quar. Bul.* 31: 12–21. 1948.
3. Overley, F. L., and O'Neill, W. J. Experiments with the use of bees for pollination of fruit trees. *Proc. Wash. State Hort. Ass'n. 42nd Ann. Meet.* 203–214. 1946.

# A Physiological Study of Post-Harvest Abscission in Pineapple Oranges

By Erston V. Miller, *University of Pittsburgh,*[1] *Pittsburgh, Pa.,* and J. R. Winston and Randall H. Cubbedge, *U. S. Department of Agriculture, Orlando, Fla.*

During the course of investigations on the development of physiological disorders of citrus fruits in storage some interesting observations were made on certain lots of oranges which had lost their stem parts during processing. Oranges are customarily harvested by clipping the stems close to the fruit so that a small portion of the stem and the calyx remains attached after harvest. These stem parts are commonly called "stem-buttons". Although stem-buttons usually remain attached until the fruits are delivered to the markets, some of the oranges lose them during handling and processing. Certain varieties, like the Pineapple orange, show this characteristic more than others, especially during the latter part of the shipping season. At that time loss of buttons may occur during actual picking and handling and particularly when the fruits are passing over the scrubbing and polishing brushes in the packing house. Separation of the fruits from the stem is referred to locally as "shattering". However, this term is used for the abscising of fruits prior to harvest as well as for the separation of the fruits from the stems during processing. Since the discussion in this paper is limited to the loss of stem-buttons during handling and processing, "post-harvest abscission" will be used instead of "shattering".

## Effect of Post-Harvest Abscission on Keeping Quality

Pineapple oranges were collected from commercial groves in different parts of Florida on approximately December 1, January 1, and February 1. The oranges were mechanically washed with flowing tap water and stored the day after picking. The storage period consisted of 4 weeks at 50 degrees F, followed by 1 week at 70 degrees. At the end of each storage period the oranges were inspected and a record was made of the percentage of physiological disorders and decay in the fruits. Relatively early in these investigations it was noted that oranges stored without stem-buttons developed more green-mold decay[2] than did those with the stem parts attached. Thereafter, whenever a marked amount of post-harvest abscission appeared in the collections, the storage samples were divided into two lots; those with and those without stem-buttons. The quantity of oranges in each lot consisted of from one to five crates, depending upon the number of abscised fruits appearing after passing through the mechanical washer. Each crate contained about 150 oranges. The results of these storage tests appear in Table I. The data represent a summary of the results obtained during three seasons with samples collected from nine different groves.

[1]Formerly Physiologist, U. S. Horticultural Field Station, Orlando, Florida.
[2]Caused by *Penicillium digitatum* Sacc.

TABLE I—GREEN-MOLD AND STEM-END DECAY IN PINEAPPLE ORANGES STORED WITH AND WITHOUT STEM-BUTTONS ATTACHED (RECORDS MADE AFTER FOUR WEEKS AT 50 DEGREES AND AGAIN AFTER ONE ADDITIONAL WEEK AT 70 DEGREES F)

| | Stored Four Weeks at 50 Degrees F | | Stored Four Weeks at 50 Degrees Followed by One Week at 70 Degrees F | |
|---|---|---|---|---|
| | Green-Mold Decay (Per Cent) | Stem-End Decay (Per Cent) | Green-Mold Decay (Per Cent) | Stem-End Decay (Per Cent) |
| With stem-buttons ........ | 1.5 | 11.5 | 9.6 | 60.5 |
| Without stem-buttons ....... | 6.6 | 21.0 | 17.7 | 21.8 |

During the storage at both temperatures there was more green-mold decay in the fruits without stem-buttons. Stem-end decay[3], on the other hand, was a little higher in fruits without buttons at 50 degrees whereas at 70 degrees F storage fruits with buttons had almost three times as much stem-end decay as did those without buttons.

## EFFECT OF OIL SPRAY ON POST-HARVEST ABSCISSION

Another observation made during these experiments was concerned with the relationship between the use of an oil spray on orange trees and the subsequent development of post-harvest abscission of the fruits. In October, 1945, 10 trees were sprayed with a 1.33 per cent oil emulsion (Florida Volck brand) and 10 comparable trees were reserved to be used as controls. These tests constituted a part of the main storage experiments and five crates of oranges were collected from each plot at the usual three periods during the season. It was only at the last collection that a significant amount of post-harvest abscission was observed. A count of the fruits after mechanical washing (Table II) revealed 2.1 per cent abscised oranges in the sprayed lots in contrast to 8.0 per cent in the controls. (No records were made of pre-harvest dropping of fruits).

The experiment was repeated during 1946. The winter of the second season was characterized by unusually warm weather with the result that there was more post-harvest abscission than previously in both lots of fruits. However, the results were still consistent with those of the previous season. The sprayed lots contained 13 per cent oranges without stem-buttons and the controls 48.6 per cent.

TABLE II—EFFECT OF OIL SPRAY ON POST-HARVEST ABSCISSION OF PINEAPPLE ORANGES (OBSERVATIONS MADE ON FIVE CRATES IN EACH PLOT)

| Date | Grove Number | Percentage of Abscised Fruits | |
|---|---|---|---|
| | | Oil Spray Plot | Control Plot |
| Feb 11, 1946 ............................ | 4 | 2.1 | 8.0 |
| Feb. 11, 1947 ............................ | 1 | 13.0 | 48.6 |

[3]Caused by either *Phomopsis citri* fawc. or *Diplodia natalensis*—Pole Evans.

## Relation of Post-Harvest Abscission to Maturity

At the time of one of the collections 200 oranges were reserved for chemical analyses. Lot 1 consisted of 100 fruits with stem-buttons attached, and lot 2 consisted of an equal number of fruits without stem-buttons. In addition to this, each lot was divided into 10 samples of 10 oranges each, so that the results might be subjected to statistical analysis. The juice of these samples was analyzed for total soluble solids, total acids, and ascorbic acid (vitamin C), using conventional methods. The results appear in Table III. No significant difference was found to exist between the two lots of fruits in regard to any of these three constituents. As may be observed by reference to the table, the difference between samples was greater than the mean differences between lots. This indicates that oranges that have lost their stem-buttons are no more mature than fruits with the stem-parts attached, because maturing of oranges is attended by an increase in total soluble solids and a decrease in total acids and ascorbic acid.

TABLE III—Solids, Acids, and Vitamin C Content in Pineapple Oranges With and Without Stem-Buttons (Each Sample Represents Ten Oranges)

| Sample Number | Solids (Per Cent) | Acid (Per Cent) | Vitamin C (Mg/100 Ml) |
|---|---|---|---|
| *With Stem-Buttons* | | | |
| 1 | 13.26 | 1.21 | 57.9 |
| 2 | 13.88 | 1.14 | 58.9 |
| 3 | 13.88 | 1.23 | 62.9 |
| 4 | 14.10 | 1.17 | 55.3 |
| 5 | 14.10 | 1.07 | 59.9 |
| 6 | 14.20 | 1.06 | 59.3 |
| 7 | 13.30 | 1.11 | 61.9 |
| 8 | 13.70 | 1.23 | 55.8 |
| 9 | 13.40 | 1.11 | 57.4 |
| 10 | 13.90 | 1.19 | 59.9 |
| Average | 13.77 | 1.15 | 58.9 |
| *Without Stem-Buttons* | | | |
| 1 | 14.60 | 1.24 | 62.4 |
| 2 | 13.74 | 1.23 | 60.9 |
| 3 | 14.15 | 1.31 | 60.9 |
| 4 | 13.68 | 1.22 | 60.4 |
| 5 | 13.44 | 1.22 | 59.9 |
| 6 | 13.84 | 1.22 | 58.9 |
| 7 | 13.34 | 1.19 | 55.3 |
| 8 | 13.94 | 1.20 | 60.4 |
| 9 | 14.34 | 1.16 | 62.4 |
| 10 | 13.84 | 1.15 | 60.4 |
| Average | 13.84 | 1.21 | 60.2 |

These tests were repeated with oranges from two additional groves and the analyses yielded similar results.

## Discussion

The oil spray in these experiments was applied to the orange trees in the fall of the year for experimental purposes. Such a procedure is not recommended commercially, although it is not an un-

common practice for the control of scale insects, especially in the warmer parts of the State. The purpose of these particular experiments was to attempt to reduce the transpiration rate of the trees in order to determine in what way the conservation of the trees' water supply would affect the keeping quality of the oranges. There is reason to believe that premature dropping of Pineapple oranges is related to the water supply of the tree since extensive periods of drought in winter are usually accompanied by an increase in the dropping of fruits. It is a common practice among nurserymen to reduce water loss from transplanted evergreens by coating the leaves with an emulsion of oil or wax. Similar treatments have been given to cherry trees in the orchard for the purpose of preventing cracking of fruits (1).

The application of the oil sprays in these experiments served to reduce the transpiration rate of the trees, at least temporarily. This was determined by quantitative tests. It is assumed, therefore, that the reduction in percentage of abscised fruits in the sprayed lots was obtained by decreasing the rate of water loss from the trees. That dropping of these fruits is not merely a maturation process is suggested by the chemical analyses which indicated no significant differences in solids, total acids, and ascorbic acid in the two types of fruits. It is generally known that a more mature orange should have higher soluble solids, lower total acids, and slightly less ascorbic acid than an immature fruit. However, the two lots of oranges in these experiments had essentially the same quantities of the above constituents.

Another interesting feature of the results is to be found in a higher percentage of abscised fruits infected with the green-mold organism, at least when stored at the lower temperatures. Meckstroth (3) reported that, under conditions favorable for the growth of *Penicillium digitatum*, pulled oranges developed more green mold than clipped ones, and there was a definite relationship between the amount of rupturing of the peel during the pulling and the subsequent development of green mold. Hopkins and Loucks (2) have reported somewhat similar results. It is generally considered that species of Penicillium gain access to the orange fruits only through abrasions in the skin. The results now being reported indicate that stem scars offer another means of entry for these particular fungi.

The large percentage of stem-end decay in the oranges stored at 70 degrees F with stem-buttons attached is in agreement with previous findings. Winston (4) stated in 1936 that "pulling" was a better method of harvesting grapefruit than "clipping", because the former method removed the stem-buttons and the organisms causing stem-end decay were apparently removed with them.

The slight excess of stem-end decay in the abscised fruits over those with stems in the 50 degree F storage may be more apparent than real, since it was not practicable to verify diagnosis by culturing the causal organism. Instead, only the fruits showing the telltale olive green spores were classed as Penicillium rots. When the decay at the stem end appeared as a tough, leathery discoloration

without spores, affecting from a quarter to a half of the surface area, it was considered stem-end decay. Although experience in making cultures from decayed oranges for a number of years has convinced the authors that visual diagnoses are almost always correct, it is still possible that green mold in its early stages could have been confused with stem-end decay in some instances.

The figures for percentage of decay in these results are slightly higher than would be expected under commercial conditions because the oranges received only the preliminary washing prior to storage rather than fungicidal baths frequently employed in commercial packing houses. Green-mold decay is almost completely controlled by these treatments although stem-end decay continues to be a major problem even in treated fruits. From a practical standpoint, therefore, it seems that oranges without stem-buttons can be held in cold storage for a while should a temporary surplus make it necessary, particularly fruit that has received a borax bath during processing.

## Summary

1. Pineapple oranges that had lost their stem-buttons developed four times as much green-mold rot as fruits with stem-buttons, when stored at 50 degrees F for 4 weeks.

2. When fruits were held for 1 week at 70 degrees F, in addition to the 4 weeks at 50 degrees F, there was nearly twice as much green-mold rot in the fruits without buttons as in those with stems attached. However, there was so much more stem-end decay in the stored fruits with buttons that the fruit without buttons still showed the best storage capacity.

3. When Pineapple orange trees were sprayed with oil in October the fruits in the last collection (February 1) showed less post-harvest abscission than those from unsprayed trees. Spraying with oil in late fall is not recommended for general orchard practice, mainly because the ill effects from frost damage might outweigh its overall beneficial effects.

4. There was no significant difference in solids, total acids, and vitamin C content of the juice when oranges with stem-buttons were compared with fruits that had lost the stem parts during handling.

## Literature Cited

1. Neal, A. L., Barr, C. G., Gardner, V. R., Rasmussen, E. J., and Miller, E. J. Influence of oil-wax emulsion sprays on size of Montmorency cherries. *Jour. Agr. Res.* 77, 9 and 10: 261–269. 1948.
2. Hopkins, E. F., and Loucks, K. W. Pulling versus clipping of oranges in respect to loss from stem-end rot and blue mold. *Proc. Fla. State Hort. Soc.* 1944: 80–86. 1944.
3. Meckstroth, G. A. Pulling versus clipping of Florida oranges. *The Citrus Industry,* 25(11): 9, 12, 18. 1944.
4. Winston, J. R. A method of harvesting grapefruit to retard stem-end rot. *U.S.D.A. Cir.* 396. 1936.

# The Effect of 2–Methyl, 4–Chlorophenoxyacetic Acid in Preventing Preharvest Drop of Apples[1]

By A. E. Mitchell, C. L. Hamner, and Walter Toenjes, *Michigan State College, East Lansing, Mich.*

Dropping of fruit prior to and during harvest is a serious fault of certain apple varieties such as the Oldenburg, Wealthy, McIntosh and Stayman. Naphthaleneacetic acid and certain of its derivatives are widely used to overcome this varietal weakness, but these chemicals have limitations and are effective for only a short period. 2, 4–dichlorophenoxyacetic acid, a relatively new growth regulator, appears to be effective in delaying fruit drop only on the Winesap and the Stayman varieties. Since 2, 4–dichlorophenoxyacetic acid seemed to be specific for Stayman and Winesap, it was conjectured that perhaps other chemicals closely resembling 2, 4–dichlorophenoxyacetic acid in chemical structure and composition such as 2–methyl, 4–chlorophenoxyacetic acid might be specific for other varieties in delaying preharvest drop of apples. Accordingly, the following experiment was undertaken to test this compound for its capacity to check fruit drop on Oldenburg, McIntosh and Northern Spy apple trees.

## Materials and Methods

Ten mature Oldenburg trees, 12 mature McIntosh trees and nine mature Northern Spy trees located at the Graham Experiment Station of the Michigan State College were selected for this study. The trees carried a medium-to-full crop of fruit. Although growing in the same environment in sod, the trees of all varieties varied somewhat in size, so that it was necessary to group the trees for each treatment, taking into consideration their size differences.

As these tests were preliminary in nature, the 10 Oldenburg trees were divided into five groups of two trees each in order to observe as

TABLE I—The Effectiveness of Various Concentrations of 2–Methyl, 4–Chlorophenoxyacetic Acid as Compared to the Sodium Salt of Naphthaleneacetic Acid in Preventing Preharvest Drop of Oldenburg Apples

| Treatment* | No. Trees | Average Cumulative Per Cent Drop at Given Dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aug 23 | Aug 25 | Aug 27 | Aug 29† | Aug 31 | Sep 2 | Sep 4 | Sep 5 |
| 2-methyl, 4-chlorophenoxyacetic acid 10 ppm | 2 | 6.0 | 9.8 | 11.0 | 25.0 | 50.8 | 60.7 | 70.1 | 73.7 |
| 2-methyl, 4-chlorophenoxyacetic acid 20 ppm | 2 | 4.6 | 5.5 | 6.1 | 10.7 | 27.3 | 36.6 | 54.4 | 60.7 |
| 2-methyl, 4-chlorophenoxyacetic acid 30 ppm | 2 | 2.3 | 2.6 | 2.9 | 3.9 | 12.6 | 15.7 | 27.7 | 34.7 |
| Sodium salt of napthaleneacetic acid** 10 ppm | 2 | 4.6 | 4.9 | 6.1 | 8.4 | 33.1 | 41.0 | 45.1 | 50.3 |
| Untreated | 2 | 5.8 | 14.1 | 20.6 | 37.5 | 60.8 | 71.1 | 83.8 | 87.4 |

*Application of treatments made on August 18, 1947 using a hydraulic sprayer.
**App-L-Set a commercial product of the Dow Chemical Company.
†Approximate date of commercial harvest.

[1]Journal Article No. 999 N. S. of the Michigan Agricultural Experiment Station.

many treatments as possible, Table I. The treatments were made on August 18, 1947 between 2 and 3 p m with a temperature of 87 degrees F. The weather at the time of the applications was bright and clear with only a slight breeze. The sprays were applied with a hydraulic sprayer, using a gun. The trees were sprayed thoroughly from opposite sides to insure complete coverage.

Based on the results of the use of 2–methyl, 4–chlorophenoxyacetic acid on Oldenburg, Table I, three treatments were selected for the McIntosh variety. The trees were divided into three groups of four trees taking into consideration size differences. The treatments are shown in Table II.

TABLE II—The Effect of 2–Methyl, 4–Chlorophenoxyacetic Acid Spray and the Sodium Salt of Naphthaleneacetic Acid Wet Dust as Preharvest Treatments to Reduce Apple Drop of McIntosh

| Treatment* | No. Trees | Average Cumulative Per Cent Drop at Given Dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sep 24 | Oct 4 | Oct 6 | Oct 8*** | Oct 10 | Oct 13 | Oct 17 | Oct 31 |
| 2-methyl, 4-chlorophenoxy-acetic acid 20 ppm applied as a spray........ | 4 | 3.3 | 4.4 | 4.7 | 5.1 | 5.9 | 9.6 | 21.0 | 59.1† |
| Sodium salt of naphthalene-acetic acid dust** 0.1 per cent applied as a wet dust | 4 | 1.7 | 3.0 | 5.1 | 10.9 | 25 3‡ | 59 3‡ | 76.9‡ | — |
| Untreated........ | 4 | 1.8 | 3.9 | 11.3 | 48.5 | 70.0§ | 87.4§ | 94.9§ | — |

*First application made September 17, 1947. Second application made September 25, 1947.

**Niagara Stik Dust a commercial product of the Niagara Sprayer and Chemical Division, Food Machinery Corporation.

***Approximate date of commercial harvest.

†Fruit on one tree was not harvested until October 31, 1947 and the number of drops were recorded at regular intervals.

‡Fruit on one tree was not harvested until October 17, 1947 and the number of drops were recorded at regular intervals.

§Fruit on two trees were not harvested until October 17, 1947 and the number of drops were recorded at regular intervals.

The first application of materials was made on September 17, 1947. The weather was bright and clear, with only a slight breeze. The 2–methyl, 4–chlorophenoxyacetic acid was applied at approximately 9 a m when the air temperature was 61 degrees F, and the wet dust treatment was made between 7 and 8 p m when the air temperature was 70 degrees F, and the conditions ideal for dusting. The trees were wet-dusted and sprayed thoroughly from opposite sides to insure complete coverage. A hydraulic sprayer and gun were used to apply the sprays. A wet duster[2] with a hand operated discharge tube was used to apply the wet dusts. The minimum air temperature for the following 24 hours was 62 degrees F and the maximum 83 degrees F, which was relatively high for this season of the year. Warm weather continued for three more days, at which time the air temperature dropped below the average for the season and remained so for a period of 10 days.

A second application applied in the same manner as the first was made September 25, 1947 as the fruit was still immature and the

[2]Material applied with a Niagara Cyclone Liqui-Duster, manufactured by the Niagara Sprayer and Chemical Division, Food Machinery Corporation, Middleport, New York.

sodium salt of naphthaleneacetic acid is usually ineffective on McIntosh after 7 to 9 days. The 2–methyl, 4–chlorophenoxyacetic acid spray was applied at approximately 4 p m, and the wet dust treatment was made 3 hours later when conditions were ideal for dusting. The air temperature at 4 p m was 50 degrees F, but it had dropped to 45 degrees F by 7 p m and reached a minimum of 31 degrees F during the night. The next day the air temperature did not go above 56 degrees F and remained relatively low for the next 7 days. This cool period was followed by seasonal temperatures.

The nine Northern Spy trees selected for this test were divided into groups of three trees each, taking into consideration size differences. The treatment of each group is given in Table III. Naphthaleneacetic acid was added to 2–methyl, 4–chlorophenoxyacetic acid in one treatment because the fruit had started to drop, and it was felt that the naphthaleneacetic acid would become effective more quickly and the 2–methyl, 4–chlorophenoxyacetic acid would remain effective for a longer period of time. The treatments were applied on October 17, 1947 at approximately 3 p m when the air temperature was 78 degrees F, and only a slight breeze. All treatments were made with an hydraulic sprayer, using a single nozzle gun.

TABLE III—The Use of 2–Methyl, 4–Chlorophenoxyacetic Acid Plus the Sodium Salt of Naphthaleneacetic Acid as Compared to 2–Methyl, 4–Chlorophenoxyacetic Acid Alone to Prevent Preharvest Drop of Northern Spy Apples

| Treatment* | No. Trees | Average Cumulative Per Cent Drop at Given Dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Oct 24 | Oct 31 | Nov 5† | Nov 7 | Nov 8 | Nov 10 | Nov 12 | Nov 14 |
| 2-methyl, 4-chlorophenoxyacetic acid 20 ppm plus sodium salt of naphthaleneacetic acid** 10 ppm | 3 | 2.5 | 3.1 | 3.2 | 3.3 | 12.8 | 13.9 | 14.3 | 14.4 |
| 2-methyl, 4-chlorophenoxyacetic acid 20 ppm | 3 | 3.5 | 4.4 | 4.5 | 4.8 | 13.2 | 14.1 | 14.3 | 14.3 |
| Untreated | 3 | 7.7 | 19.6 | 29.5 | 34.7 | 57.1 | 58.1 | 58.7 | 58.8 |

*Application of treatments made on October 17, 1947 using a hydraulic sprayer.
**App-L-Set a commercial product of the Dow Chemical Company.
†Approximate date of commercial harvest.

The counts to determine the number of dropped fruits were made at 3-, 2-, and 1-day intervals for each of the three apple varieties, the time interval determined by the daily rate of fruit drop.

Whenever 2–methyl, 4–chlorophenoxyacetic acid was used in these tests, the crystals were first dissolved in 95 per cent ethyl alcohol and the resulting solution was then added to the water in the sprayer tank.

## Results and Discussion

The data in Tables I, II, and III summarize the results from the use of 2–methyl, 4–chlorophenoxyacetic acid on Oldenburg, McIntosh, and Northern Spy apple trees, to prevent preharvest fruit drop. It also compares this treatment with treatments of the sodium salt of naphthaleneacetic acid.

*Oldenburg Variety:*—The data in Table I show 2–methyl, 4–chlorophenoxyacetic acid at 30 p p m as the most effective treatment in preventing preharvest fruit drop. There was very little difference throughout the entire experiment between the effectiveness of the sodium salt of naphthaleneacetic acid at 10 p p m and 2–methyl, 4–chlorophenoxyacetic acid at 20 p p m. However, 2–methyl, 4–chlorophenoxyacetic acid at 10 p p m was only a little better than no treatment. The commercial picking for Oldenburg apples was considered approximately August 29, 1947. The average cumulative per cent fruit drop at this time was only 3.9 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 30 p p m as compared to 8.4 per cent for the sodium salt of naphthaleneacetic acid at 10 p p m, 10.7 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 20 p p m, 25 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 10 p p m, and 37.5 per cent for no treatment.

Records were continued beyond the commercial harvest date to determine the period of time the various concentrations of 2–methyl, 4–chlorophenoxyacetic acid would remain effective. On August 31, 1947, only 2 days after the commercial picking date, the average cumulative per cent drop had increased to 50.8 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 10 p p m, 27.3 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 20 p p m, 12.6 per cent for 2–methyl, 4–chlorophenoxyacetic acid at 30 p p m, 33.1 per cent for the sodium salt of naphthaleneacetic acid at 10 p p m, and 60.8 per cent for no treatment.

*McIntosh Variety:*—The data present in Table II shows that two applications of 2–methyl, 4–chlorophenoxyacetic acid at 20 p p m were more effective than two applications of the sodium salt of naphthaleneacetic acid at 10 p p m in preventing preharvest drop of McIntosh apples.

The commercial picking date was considered October 8, 1947 at which time the trees treated with 2–methyl, 4–chlorophenoxyacetic acid had an average cumulative per cent drop of 5.13 per cent; those treated with the sodium salt of naphthaleneacetic acid, 10.9 per cent; and those receiving no treatment, 48.52 per cent. At this time two check trees and three trees treated with the sodium salt of naphthaleneacetic acid were harvested.

The fruit was allowed to remain on the other experimental trees so as to observe the effectiveness of the growth regulators over a longer period of time. One week following commercial harvest, October 15, 1947, the drop from untreated trees reached 91.74 per cent of the crop compared with only 13.55 per cent from the trees treated with 2–methyl, 4–chlorophenoxyacetic acid and 71.18 per cent from the unharvested tree treated with the sodium salt of naphthaleneacetic acid. By the end of the test, October 15, 1947, these percentages had increased to 23.99 per cent for trees treated with 2–methyl, 4–chlorophenoxyacetic acid, 94.89 per cent for the untreated trees and 76.85 per cent for the unharvested tree of the sodium salt of naphthaleneacetic acid treatment. At this time practically all the fruit remaining on these trees were overripe and unpalatable. For interest, one tree of

the 2-methyl-4-chlorophenoxyacetic acid treatment was left unharvested until October 31, 1947 and at that time 40.9 per cent of the apples were still hanging on the tree.

*Northern Spy Variety:*—The detailed record of this test is given in Table III. As the fruit had started to drop at the time the treatments were made, it was conjectured that perhaps the sodium salt of naphthaleneacetic acid would become effective in delaying fruit abscission more quickly than would 2-methyl, 4-chlorophenoxyacetic acid and that this latter material would have a longer duration of effectiveness. Accordingly, the two growth regulators were used together. However, the greatest difference between the average cumulative per cent drop between the two treatments was 1.52 per cent on November 7, 1947. At this time the sodium salt of naphthaleneacetic acid plus 2-methyl, 4-chlorophenoxyacetic acid treated trees had dropped 3.29 per cent of their fruit while the trees treated with 2-methyl, 4-chlorophenoxyacetic acid alone had a fruit drop of 4.81 per cent. By contrast the fruit on the trees receiving no treatment had dropped 34.72 per cent. At the time the experiment was terminated, November 14, 1947, 9 days after commercial harvest, the drop from the trees treated with the sodium salt of naphthaleneacetic acid plus 2-methyl, 4-chlorophenoxyacetic acid was 14.35 per cent, those treated with 2-methyl, 4-chlorophenoxyacetic acid alone 14.33 per cent and those receiving no treatment 58.80 per cent.

*General:*—While the results from these preliminary tests with 2-methyl, 4-chlorophenoxyacetic acid suggest its value as a material to retard the fruit drop of Oldenburg, McIntosh and Northern Spy apple varieties, there are several points that should be considered. First, the 1947 season of maturity for the three fruit varieties was 2 weeks later than the average for Michigan on account of an unusually late spring. Also July, August and September were exceedingly dry. The temperature during August was normal, however, in September the weather was unusually warm prior to and for several days after the first hormone treatment was made on McIntosh. A cool spell followed which was in turn followed by warmer but normal temperatures. Under these latter conditions the fruit drop of McIntosh was accelerated. Whether these conditions were unduly favorable to 2-methyl, 4-chlorophenoxyacetic acid can only be determined by additional work. Further, the trees used in all these tests were a mixture of variety strains; that is, the trees used in this experiment were in a block of bud sports which included Oldenburg, McIntosh and Northern Spy. In previous years no evidence has been noted of any differences in fruit drop among these bud sports. Nevertheless, this factor remains which can be eliminated only by further tests.

The results of this preliminary work with 2-methyl, 4-chlorophenoxyacetic acid show sufficient promise to justify the continuation of a more extensive research program in the use of this materials to reduce preharvest drop of apples, especially on the McIntosh variety.

## Summary

2-methyl, 4-chlorophenoxyacetic acid was effective in controlling preharvest drop of Oldenburg, McIntosh and Northern Spy apples when used at concentrations of 20 p p m and 30 p p m. The sodium salt of naphthaleneacetic acid at 10 p p m added to 2-methyl, 4-chlorophenoxyacetic acid at 20 p p m gave no more protection in preventing preharvest drop of Northern Spy apples than did 2-methyl, 4-chlorophenoxyacetic acid alone at 20 p p m.

## Literature Cited

1. Batjer, L. P., and Thompson, A. H. Effects of 2,4-dichlorophenoxyacetic acid sprays in controlling the harvest drop of several apple varieties. *Proc. Amer. Soc. Hort. Sci.* 47: 35–38. 1946.
2. Harley, C. P., Moon, H. H., Regeimbal, L. O., and Green, E. L. 2,4-dichlorophenoxyacetic acid as a spray to reduce harvest fruit drop of apples. *Proc. Amer. Soc. Hort. Sci.* 47: 39–43. 1946.

# Further Studies on the Influence of Methyl A-Naphthalene-acetate on Ripening of Apples and Peaches[1]

By F. W. SOUTHWICK, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

RECENT reports (1, 2, 3, 6, 8) indicate that under certain conditions applications of naphthaleneacetic acid type compounds may hasten ripening of some deciduous fruits. This influence has been recorded following tree applications of such materials for prevention of pre-harvest drop and after such materials were applied as dips or dusts to freshly harvested, unripened (pre-climacteric) fruit. Its influence appears to be somewhat analogous to that obtained when immature apples are subjected to ripe apple vapors (5). However, it has been shown (5) that ripe apple vapors have an influence on the rate of respiration and softening of other apples that are in their pre-climacteric phase but not at later stages of maturity.

Consequently, the results of Marshall, Hamner, and Kremer (4), indicating that methyl a-naphthaleneacetate (referred to as MENAA in the text) retarded ripening of apples, seem unique. It is apparent that the apples used in their tests were either about at their respiratory climacteric or post-climacteric since their experiments with Grimes, Jonathan, and McIntosh commenced in November and December. Pre-climacteric apples in cold storage will generally pass into the climacteric or post-climacteric phase after a few weeks in storage. Also, when apples are placed in cold storage they are very apt to be exposed to the ripening influence of ethylene and possibly other ripening vapors, arising from riper lots of apples already in the room.

The difference between the results obtained by Marshall, Hamner, and Kremer (4) and the author (8) with MENAA appear to be explainable on the basis of differences in maturity of the fruit used. Consequently, data are presented relating to the influence of MENAA on the rate of respiration and softening on peaches and apples with their stage of maturity.

## METHODS AND MATERIALS

The respiration measurements were made from composited lots of fruit containing 20 or more blemish-free specimens each. The time of picking and the conditions under which the fruit was held prior to treatment are indicated in the text. Each lot of fruit was placed in a half bushel glass container and submerged in a constant temperature (74 degrees F) water bath during the period when the measurements were made. The rate of respiration was determined by measuring the milligrams of carbon dioxide produced per kilogram of fruit per hour, as previously discussed (6).

Changes in the firmness of the flesh were determined with a Magness-Taylor pressure tester. The New York ground color chart for McIntosh apples (9) was employed to determine the influence of

[1]Contribution No. 702 of the Massachusetts Agricultural Experiment Station.

treatment on this factor. There are five colors on this chart, ranging from yellow (No. 1) to green (No. 5).

The materials tested were vapors from ripe peaches, oil-impregnated wrappers, and various preparations of the methyl ester of a-naphthaleneacetic acid.

## Results

*Peaches:*—The Elberta peaches used in this experiment were harvested on September 11, 1946, at Sodus, New York, and transported the same day to Ithaca, New York. The rate of respiration of three similar lots was determined the following day before any treatments were made. Following the initial determination on September 12, one lot was subjected to the vapors from six ripe Elberta peaches for 2 days while shredded paper containing 2 per cent MENAA was distributed amongst the fruit in a second container. Fig. 1 and Table I show the influence of these treatments on the rate of respiration and ground color changes, respectively.

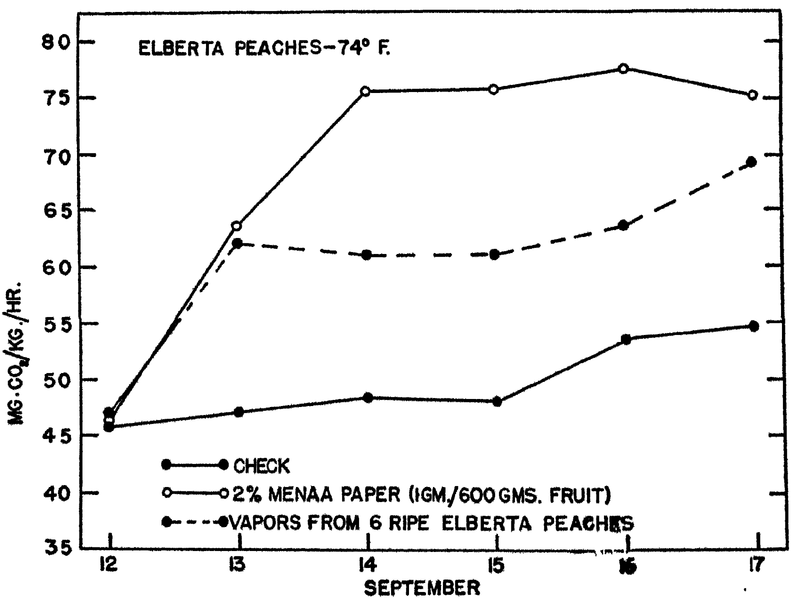



Fig. 1. The influence of MENAA and ripe peach vapors on the rate of respiration of pre-climacteric Elberta peaches.

From the data presented in Fig. 1 and Table I it is apparent that both MENAA and vapors from ripe peaches are capable of stimulating the rate of respiration, softening, and ground color development. It has been determined, however, that when the lots of peaches are somewhat more mature they may show no significant response to MENAA treatments. This may be true even though the peaches are not eating ripe. For instance, a lot of Halehaven peaches, although immature and

TABLE I—INFLUENCE OF METHYL A-NAPHTHALENEACETATE AND RIPE PEACH VAPORS ON THE SOFTENING AND GROUND COLOR OF PRE-CLIMACTERIC ELBERTA PEACHES

| Treatment | Average Firmness (Lbs) | | Ground Color After 6 Days (at 70 Degrees F) |
|---|---|---|---|
| | At Harvest (Sep 11, 1946) | After 6 Days (at 70 Degrees F) | |
| Check | 27 7 | 15.6 | Mostly green |
| 2 per cent MENAA on shredded paper (1 gm /600 gms fruit) | 27.7 | 3.5 | Yellow |
| Vapors from six ripe Elberta peaches (Sep 12 to 14 | 27.7 | 8.2 | Mixed yellow and green |

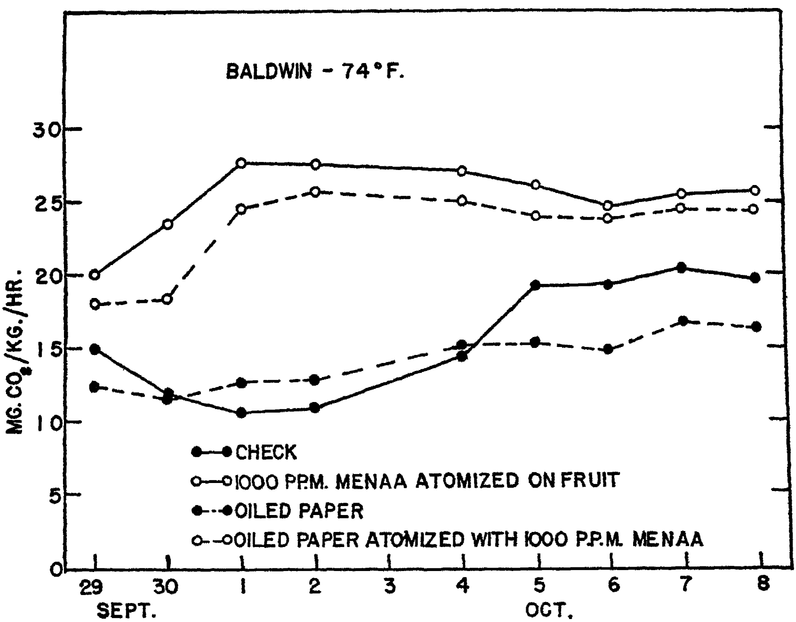



FIG. 2. The influence of MENAA and oiled paper wraps on the rate of respiration of pre-climacteric Baldwin apples.

having an average firmness of about 20 pounds, were treated with varying amounts of MENAA yet they failed to soften or yellow any faster than untreated lots. Within 4 days at room temperature all lots had an average firmness of 3 to 4 pounds. It seems apparent that the peaches in this instance had commenced their climacteric rise of respiration and that MENAA had no measurable influence on respiration, softening, or ground color changes at this time.

*Apples:*—To determine the influence of MENAA on pre-climacteric apples a lot of immature Baldwins were harvested on September 28, 1949, at Amherst. An attempt was made to simulate the experiment of Marshall *et al* (4) by atomizing MENAA at 1000 ppm. The treatments were applied immediately after the fruit was harvested and the

respiration measurements commenced on September 29. Data on respiration and firmness and ground color changes are given in Fig. 2 and Table II, respectively.

TABLE II—INFLUENCE OF METHYL A-NAPHTHALENEACETATE AND OIL PAPER WRAPS ON THE SOFTENING AND GROUND COLOR OF PRE-CLIMACTERIC BALDWINS

| Treatment | Average Firmness (Lbs) | | Ground Color After 11 Days (at 74 Degrees F) |
|---|---|---|---|
| | At Harvest Sep 28, 1948 | After 11 Days (at 74 Degrees F) | |
| Check | 20 2 | 18.7 | 4–5 |
| Oil paper wrapped | 20.2 | 17.6 | 3–4 |
| Oil paper wrapped (paper atomized with 1000 ppm MENAA) | 20.2 | 17.0 | 2–3 |
| Fruit atomized with 1000 ppm MENAA | 20.2 | 17.0 | 3 |

Data in Fig. 1 and Table II indicate that MENAA at 100 ppm either on oiled paper wraps or alone will hasten the appearance of the respiratory climacteric and stimulate the rate of softening and ground color changes of pre-climacteric apples. There is a suggestion in Table II that oiled paper wraps alone may hasten softening and the development of a yellow ground color.

Fig. 3 represents a similar series of treatments on McIntosh apples which had been picked in mid-September and held in mixed variety

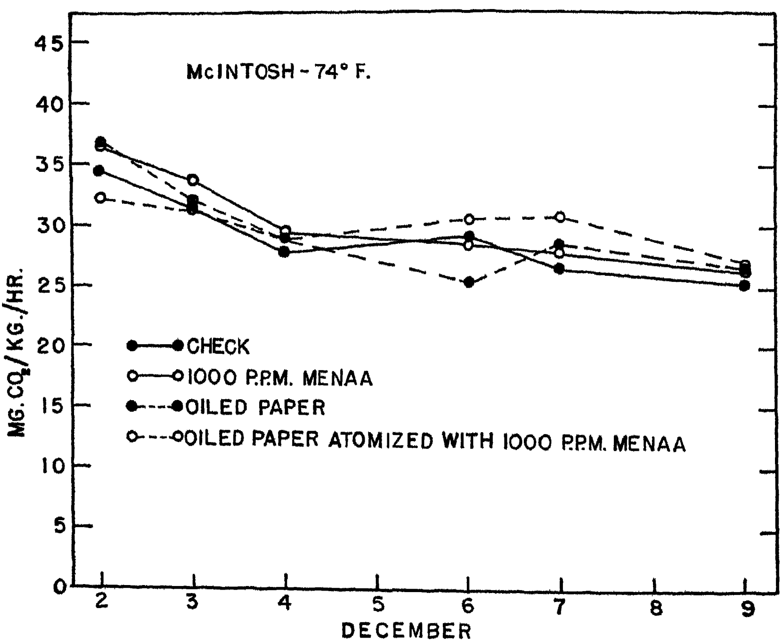



FIG. 3. The influence of MENAA and oiled paper wraps on the rate of respiration of post-climacteric McIntosh apples.

storage at 32 degrees F until December. On December 1, 1948, they were taken from storage, allowed to come to room temperature and treated in an identical manner as the Baldwins previously discussed.

The data in Fig. 3 show that the rate of respiration of this post-climacteric lot of apples was not significantly influenced by any of the treatments. This is typical of other results obtained by the author with other lots of apples which were well advanced in their climacteric rise or were post-climacteric at the time of treatment with MENAA. None of the treatments had any significant influence on the firmness or ground color development.

## Discussion

Results obtained with the methyl ester of a-naphthaleneacetic acid show that it is capable of stimulating the rate of respiration, softening, and ground color changes of pre-climacteric apples and peaches held at room temperatures. Once the pre-climacteric phase has passed the fruit may show no response to the material under the conditions reported here. Its influence in these respects seems similar to those obtained from ripe fruit vapors (5). No indications of an inhibition of ripening process of apples and peaches have been noticed during any stage of their post-harvest storage life.

## Literature Cited

1. Batjer, L. P., and Moon, H. H. Effect of naphthaleneacetic acid spray on maturity of apples. *Proc. Amer. Soc. Hort. Sci.* 46: 113–117. 1945.
2. Batjer, L. P., and Thompson, A. H. The transmission of effect of naphthaleneacetic acid on apple drop as determined by localized applications. *Proc. Amer. Soc. Hort. Sci.* 51: 77–80. 1948.
3. Gerhardt, F., and Allmendinger, D. F. The influence of a-naphthaleneacetic acid spray on the maturity and storage physiology of apples, pears, and sweet cherries. *Jour. Agr. Res.* 73: 189–206. 1946.
4. Marshall, R. E., Hamner, C. L., and Kremer, J. C. Retardation of ripening of fruits with the methyl ester of naphthaleneacetic acid. *Proc. Amer. Soc. Hort. Sci.* 51: 95–96. 1948.
5. Smock, R. M. The influence of stored apples on the ripening of other apples stored with them. *N. Y. (Cornell) Agr. Exp. Sta. Bul.* 799. 1943.
6. ———— and Gross, C. R. The effect of some hormone materials on the respiration and softening rates of apples. *Proc. Amer. Soc. Hort. Sci.* 49: 67–77. 1947.
7. Southwick, F. W. The influence of methyl bromide on the rate of respiration and softening of apples. *Proc. Amer. Soc. Hort. Sci.* 46: 152–158. 1945.
8. ———— Effect of some growth-regulating substances on the rate of softening, respiration, and soluble solids content of peaches and apples. *Proc. Amer. Soc. Hort. Sci.* 47: 84–90. 1946.
9. ———— and Hurd, M. Harvesting, handling, and packing apples. *N. Y. Agr. Col. (Cornell) Ext. Bul.* 750 (Supplement). 1948.

# Hard End and Cork Spot of Pears as Influenced by High-Concentration Hormone Sprays[1]

By R. M. BULLOCK and WM. B. ACKLEY, *Washington Experiment Stations, Pullman, Wash.*

HARD END or black end, a physiological disorder of pear fruits, causes severe losses to the Bartlett pear industry of the Pacific Coast each year. This disease is generally associated with the pear rootstock, *Pyrus serotina,* but the exact cause of the disorder never has been satisfactorily determined. A number of workers have indicated, however, that an unfavorable water balance within the tree may be linked with the occurrence of this disease (1, 2, 3, 4, 5). Cork spot, another physiological disorder of pears, is particularly serious on the variety Beurre d'Anjou. Its symptoms are quite different from those of hard end, but its causal effects often are considered as being the same.

During the summer of 1948 a fruit grower in the Yakima Valley of Washington sprayed, by mistake, a small block of apple and pear trees with two applications of 2,4-D weed killer containing approximately 120 ppm 2,4-D acid. The first application was made about July 2 and the second, July 18. The pear trees were of the variety Bartlett and were carrying a good crop of fruit. Shortly following the second application, the leaves became extremely wilted, new growth was abnormal, 15 to 20 per cent of the fruit cracked longitudinally, and nearly 100 per cent of the fruit showed symptoms of the disorder hard end.

These observations lead to a preliminary test to induce hard end and cork spot through the use of high concentrations of 2,4-dichlorophenoxyacetic acid and naphthalene acetic acid sprays on the fruit of Bartlett and Anjou pears late in the growing season. This test was conducted at the Tree Fruit Experiment Station, Wenatchee, Washington.

Separate comparable limbs on the same Anjou pear tree were selected for spraying with these two materials. A similar limb on the same tree was left unsprayed to serve as a check. This tree was selected for its high state of vigor and its large crop of fruit which appeared normal at the time of application of the sprays. Cork spot history of this tree, for the period, 1941 to 1947 inclusive, averaged 7.5 per cent. Individual young Bartlett trees were selected for spraying with these two materials and as a check on the same basis. Separate trees were used for each treatment. The sprays were applied August 16. The Bartletts were harvested September 1, 15 days following treatment, while the Anjous were harvested September 15, 30 days after treatment. The concentrations of the materials were as shown in Table I.

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[1]Published as Scientific Paper No. 816, College of Agriculture and Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman, Washington.

TABLE I—CORK SPOT OF ANJOU PEARS AS AFFECTED BY HIGH CONCENTRATIONS OF 2,4-D AND NAPHTHALENE ACETIC ACID SPRAYS APPLIED 30 DAYS BEFORE HARVEST

| Treatment | Concentration (Ppm) | Total Fruits | Normal Fruits | Cork-Spotted Fruits | |
|---|---|---|---|---|---|
| | | | | Number | Per Cent |
| Check | — | 116 | 109 | 7 | 6.0 |
| Naphthalene acetic acid | 100 | 71 | 62 | 9 | 12.7 |
| | 200 | 59 | 51 | 8 | 13.6 |
| | 300 | 108 | 77 | 31 | 28.7 |
| 2,4-D | 100 | 77 | 31 | 46 | 60.0 |
| | 200 | 100 | 30 | 70 | 70.0 |
| | 300 | 111 | 5 | 106 | 95.5 |

At harvest, each fruit was examined externally and then cut for internal examination. It was found that the naphthalene acetic acid sprays applied to the Anjou pears 30 days before harvest increased the percentage of fruit showing cork spot as compared to the check fruit. This increase was progressive through the concentrations tested. The 2,4-D sprays increased the amount of cork-spotted fruit markedly over both the check fruit and over the naphthalene acetic acid sprayed fruit. Here, also, the effect was progressive through the concentrations used, 95.5 per cent diseased fruit being produced at 300 ppm. While the lower concentrations of 2,4-D gave high percentages of cork-spotted fruit, the cork areas were progressively more difficult to find as the spray concentration was lowered.

When applied 15 days before harvest, the effect of these two materials on Bartlett pears was apparent only in the advancement of maturity of the fruit and the severity of core breakdown. Presumably, the sprays were not applied early enough to induce hard end. The 2,4-D sprays on Bartletts hastened maturity at all concentrations and increased the percentage of core breakdown up to 62 per cent at 300 ppm. The fruit receiving the 2,4-D sprays, in many cases, had a mottled yellow and green color which increased in intensity as the concentrations were increased. In contrast, the naphthalene acetic acid sprays had little influence on maturity except at 300 ppm which gave a uniform yellow coloring and 4 per cent core breakdown.

Advanced maturity was also apparent in the Anjou pears sprayed with 2,4-D, the effect being in direct relation to the concentration of the spray. The naphthalene acetic acid sprays, however, caused only a slight apparent change in maturity.

From these observations, it may be concluded that hard end of Bartlett pears, cork spot of Beurre d'Anjou pears, and maturity of these two varieties may all be influenced by high concentrations of certain hormone sprays.

It is recognized that hormones have an influence on the water balance within a plant and this may be the possible explanation for the effects reported here.

## Literature Cited

1. Barss, H. P. Physiological disorders of developing fruits. *Biennial Crop Pest and Horticultural Report, Ore. Agr. Exp. Sta.* 3: 159–166. 1920.
2. Heald, F. D. Manual of Plant Diseases. McGraw-Hill Book Co., New York. 1933.
3. Heppner, M. J. Pear black-end and its relation to different rootstocks. *Proc. Amer. Soc. Hort. Sci.* 24: 139–142. 1927.
4. MacKelvie, A. D. Hard End in Bartlett pears. *Proc. Wash. State Hort. Assoc.* 36: 111–112. 1940.
5. Tufts, W. P., and Davis, L. D. Hard-end or black-end of pears in California. *Proc. Wash. State Hort. Assoc.* 25: 108–116. 1929.

# Preliminary Study of the Effects of Waxing on Weight Loss and Keeping Quality of Apples[1]

By J. E. LINDE, JR., and W. C. KENNARD, *The Pennsylvania State College, State College, Penn.*

A CONSIDERABLE portion of the experimental work with waxes reported by other workers has been concerned with the retardation of storage breakdown and the reduction of moisture loss. Smock (3) reported that the most consistent and desirable effect that can be expected from waxing is the reduction in weight loss of the fruit, and that the result of holding apples in low relative humidities in storage or in the market place can be partially overcome by the use of suitable wax emulsions. Hitz and Haut (1) and Pieniazek and Christopher (2) also found that moisture loss was considerably decreased by wax emulsions. The waxes used by the authors mentioned were Brytene emulsions, number 489A being the one most frequently used.

The waxing in the tests reported herewith was performed on November 4, 1947, by means of a demonstration waxer provided by the John Bean Corporation. The waxing unit consisted of a small grading table, a chamber in which the apples were rotated as they passed under a gravity spray which applied a uniform coating of wax, and a drying unit in which fast moving electrically heated air was used to dry the wax on the apples.

The waxes used were: (a) No. 27X, (b) No. 810, and (c) No. 860, all from the John Bean Corporation. Wax No. 810 is recommended by the manufacturer for yellow varieties and is not of high luster; wax No. 860 is recommended for red varieties and is of medium luster; while wax No. 27X is a general purpose, high luster wax.

Orchard run Grimes Golden and Stayman Winesap, and Rome Beauty drop apples, all of which had been held from the time of harvesting until waxing in cold storage, were used in these tests. When the apples were waxed the temperature and humidity were such that the waxes did not dry readily. Five bushels of each variety were treated with each of the above named waxes, and from these 5 bushels in each treatment 24 fruits of high color[2] and 24 of low color were selected for uniformity of size and condition. These two lots each were divided into two groups of 12 apples each, one group wrapped with oiled apple wraps and the other unwrapped. This combination of treatments made possible the study of the effects of the waxes and the effects of oiled wraps on weight loss in fruits of both low and high color.

Each group of 12 apples was weighed on November 5, 1947, placed in 4-quart open containers and set out on a table in the laboratory where the temperature fluctuated between 65 and 75 degrees F. Subse-

[1]Authorized for publication on August 10, 1948, as paper No. 1459 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2]High color in Grimes Golden apples was considered to be a definite yellowing of the ground color. In the other two varieties high color refers to the amount of over color.

quent weighings were made on November 10, 17, and 21. On November 21 several of the untreated and a few of the waxed Rome Beauty apples had begun to show decay, and the control samples of all three varieties showed considerable loss in firmness; consequently, the experiment was concluded. The loss in weight was calculated as the percentage of the original weight.

Each figure in Table I is an average for four treatments of 12 apples each (a) high color, wrapped, (b) low color, wrapped, (c) high color, unwrapped, and (d) low color, unwrapped. In each case waxing decreased the percentage weight loss.

TABLE I—Percentage Weight Loss After 16 Days at Room Temperature Due to the Effect of Waxing

| Treatment | Weight Loss (Per Cent) | | | Average For All Varieties |
|---|---|---|---|---|
| | Stayman Winesap | Grimes Golden | Rome Beauty | |
| Check | 0.90 | 0.97 | 0.59 | 0.82 |
| Wax No. 27X | 0.73 | 0.77 | 0.51 | 0.67 |
| Wax No. 810 | 0.63 | 0.73 | 0 51 | 0.63 |
| Wax No. 860 | 0.70 | 0.75 | 0.53 | 0.66 |

Results of wrapping are shown in Table II. Comparison of wrapped and unwrapped apples indicates that oiled wraps had little or no effect on weight loss during the 16 days these apples were under test at room temperature.

TABLE II—Percentage Weight Loss After 16 Days at Room Temperature of Wrapped and Unwrapped Apples Under Different Waxing Treatments

| Treatment | Wrapped | Unwrapped | Increase in Percentage of Loss Due to Wrapping |
|---|---|---|---|
| *Stayman Winesap* | | | |
| Check | 0.92 | 0.90 | +0.02 |
| Wax No. 27X | 0.76 | 0.71 | +0.05 |
| Wax No. 810 | 0.60 | 0.65 | −0.05 |
| Wax No. 860 | 0.73 | 0.68 | +0.05 |
| *Grimes Golden* | | | |
| Check | 1.00 | 0.96 | +0.04 |
| Wax No. 27X | 0.81 | 0.74 | +0.07 |
| Wax No. 810 | 0.74 | 0.71 | +0.03 |
| Wax No. 860 | 0.80 | 0.74 | +0.06 |
| *Rome Beauty* | | | |
| Check | 0.60 | 0.59 | +0.01 |
| Wax No. 27X | 0.52 | 0.50 | +0.02 |
| Wax No. 810 | 0.51 | 0.51 | 0.00 |
| Wax No. 860 | 0.53 | 0.54 | −0.01 |

The differences in weight loss between high and low color are shown in Table III. Except for one variety, Grimes Golden, the fruit of low color lost significantly more weight than did that of high color. In all cases low color Stayman Winesap and Rome Beauty apples showed a greater weight loss than high color fruit. This exception of Grimes Golden is due most likely to the fact that it was

difficult to determine the differences in degree of maturity of this yellow variety.

TABLE III—PERCENTAGE WEIGHT LOSS IN APPLES OF HIGH AND LOW COLOR UNDER DIFFERENT WAXING TREATMENTS

| Treatment | High Color | Low Color | Difference in Percentage of Loss Between Low and High Color |
|---|---|---|---|
| | *Stayman Winesap* | | |
| Check | 0.88 | 0.94 | +0.06 |
| Wax No. 27X | 0.68 | 0.78 | +0.10 |
| Wax No. 810 | 0.59 | 0.67 | +0.08 |
| Wax No. 860 | 0.68 | 0.73 | +0.05 |
| | *Grimes Golden* | | |
| Check | 0.97 | 0.98 | +0.01 |
| Wax No. 27X | 0.79 | 0.76 | −0.03 |
| Wax No. 810 | 0.72 | 0.74 | +0.02 |
| Wax No. 860 | 0.79 | 0.75 | −0.04 |
| | *Rome Beauty* | | |
| Check | 0.57 | 0.62 | +0.05 |
| Wax No. 27X | 0.50 | 0.52 | +0.02 |
| Wax No. 810 | 0.49 | 0.53 | +0.04 |
| Wax No. 860 | 0.52 | 0.54 | +0 02 |

At the conclusion of the experiment little difference could be observed in appearance of apples among wax treatments, although there was a noticeable superiority of waxed fruits over untreated fruits. In Rome Beauty, where drop apples were used, the incidence of decay was greater in the unwaxed fruit than in the waxed fruits.

TABLE IV—NUMBER OF ROME BEAUTY APPLES SHOWING DECAY ON NOVEMBER 21, 1947

| | Check | Wax No. 27X | Wax No. 810 | Wax No. 860 |
|---|---|---|---|---|
| Number of apples in test | 48 | 48 | 48 | 48 |
| Percentage of decayed apples | 29.2 | 0.42 | 0.42 | 0.21 |

The remainder of the apples in each treatment was packed in bushel boxes and placed in cold storage at approximately 34 degrees F. One bushel of Grimes Golden for each of the waxing treatments was wrapped. All the other apples were packed without oiled paper wraps. On April 7, 1948, the apples were removed from storage and the numbers of apples showing rot, surface scald, and other types of breakdown were recorded.

The data in Table V show a higher percentage of sound fruit in the waxed Rome Beauty and Grimes Golden apples than in the checks. No consistent differences, however, existed among waxing treatments. The unwaxed Stayman Winesap apples used in this test were superior to the waxed fruit after 5 months in cold storage, indicating no benefit from the waxes.

No consistent decrease in the amount of surface scald could be noted in the waxed fruit, and the data indicate that waxing increased the amount of scald on the Rome Beauty and Stayman Winesap apples.

TABLE V—CONDITION OF APPLES AFTER STORAGE AT 34 DEGREES F FOR FIVE MONTHS

| Treatment | Sound Fruit | | Decay | | Scald | | Breakdown | |
|---|---|---|---|---|---|---|---|---|
| | No. | Per Cent | No. | Per Cent | No. | Per Cent | No. | Per Cent |
| *Rome Beauty (Unwrapped)* | | | | | | | | |
| Check | 140 | 69.0 | 52 | 25.6 | 0 | 0.0 | 11 | 5.4 |
| Wax No. 27X | 190 | 78.2 | 41 | 16.9 | 2 | 0.8 | 10 | 4.1 |
| Wax No. 810 | 265 | 76.8 | 65 | 18 8 | 6 | 1 7 | 9 | 2.6 |
| Wax No. 860 | 187 | 77.3 | 45 | 18.6 | 5 | 2 1 | 5 | 2.1 |
| *Grimes Golden (Unwrapped)* | | | | | | | | |
| Check | 374 | 76.5 | 81 | 16 6 | 34 | 7.0 | 0 | 0 |
| Wax No. 27X | 297 | 85.6 | 21 | 6.1 | 28 | 8.1 | 0 | 0 |
| Wax No. 810 | 307 | 85.0 | 28 | 7.8 | 26 | 7.2 | 0 | 0 |
| Wax No. 860 | 294 | 85.7 | 32 | 9.3 | 17 | 5.0 | 0 | 0 |
| *Grimes Golden (Wrapped)* | | | | | | | | |
| Check | 124 | 93.2 | 3 | 2.3 | 6 | 4 5 | 0 | 0 |
| Wax No. 27X | 137 | 96.5 | 3 | 2.1 | 2 | 1.4 | 0 | 0 |
| Wax No. 810 | 130 | 94.9 | 5 | 3.7 | 2 | 3.7 | 0 | 0 |
| Wax No. 860 | 117 | 95.9 | 4 | 3.3 | 1 | 0.8 | 0 | 0 |
| *Stayman Winesap (Unwrapped)* | | | | | | | | |
| Check | 128 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0 |
| Wax No. 27X | 118 | 97.6 | 2 | 1.7 | 1 | 0.8 | 0 | 0 |
| Wax No. 810 | 228 | 97.4 | 0 | 0.0 | 6 | 2.6 | 0 | 0 |
| Wax No. 860 | 194 | 99.5 | 1 | 0.5 | 0 | 0 0 | 0 | 0 |

## SUMMARY

A. The following results were found when the apples were stored for 16 days at room temperature:

1. All wax treatments reduced the weight loss of apples.
2. Oiled paper wraps did not materially affect the weight loss of apples.
3. In the case of Stayman Winesap and Rome Beauty apples low color fruit suffered greater weight loss than did high color fruit.
4. Waxed Rome Beauty apples showed less decay than unwaxed fruit.

B. A higher percentage of sound Grimes Golden and Rome Beauty apples was found in the wax treatments than in the checks when the apples were stored for 5 months at 34 degrees F. The waxes did not benefit Stayman Winesap apples under the same conditions.

### LITERATURE CITED

1. HITZ, C. W., and HAUT, I. C. Effects of waxing and pre-storage treatment upon prolonging the edible and storage qualities of apples. *Md. Bul. No. A 14. (Technical)* 1942.
2. PIENIAZEK, S. A., and CHRISTOPHER, E. P. Relation of the time factor to the influence of concentration of wax emulsion on the reduction of the rate of transpiration of apples. *Proc. Amer. Soc. Hort. Sci.* 46: 119–122. 1945.
3. SMOCK, R. M. Some additional effects of waxing apples. *Proc. Amer. Soc. Hort. Sci.* 37: 448–452. 1940.

# Ultraviolet Light Treatment of Peaches, Nectarines, and Plums for the Control of Transit Decay

By D. H. DEWEY and W. T. PENTZER, *U. S. Department of Agriculture, Fresno, Calif.*

SHIPPERS of peaches, nectarines, and plums are constantly confronted with the problem of preventing decay of their fruit while it is in transit to distant markets. Inadequate precooling and refrigeration are often the chief contributing factors; but some rots grow even at 40 degrees F, and damage may be expected in 1 to 2 weeks if the fruit is infected when shipped. In an effort to prevent the growth of incipient infections, especially those of Rhizopus and brown rot, ultraviolet irradiation has been used on a commercial scale in some packing sheds. Since no studies have been reported on its application to peaches, nectarines, and plums and the results obtained in the treatment of oranges by Fulton and Coblentz (2) and of sweet cherries by English and Gerhardt (1) have shown that ultraviolet irradiation is of doubtful practical value, it seemed desirable to determine the effectiveness of the treatment as a means of controlling decay of these stone fruits. The tests herein reported dealt primarily with naturally inoculated fruit handled in a commercial manner with and without ultraviolet light treatment. In addition, there were several tests of the light treatment on artificially inoculated fruit.

## ULTRAVIOLET LIGHT EQUIPMENT

The ultraviolet light equipment employed in these tests was a commercial installation consisting of low-pressure mercury arc lamps operating on 110 to 115 volts. The lamps were mounted in batteries containing 36-inch (30-watt) and 18-inch (15-watt) lamps, each lamp being centered in a concave polished aluminum reflector and mounted with the 36-inch and 18-inch lamps end to end. The reflectors were 5 inches in width and the lamps were consequently approximately 5 inches apart when mounted adjacent to each other. The batteries of lights were aligned over the conveyor of the grader so that the fruit was exposed to the ultraviolet light for 35 seconds at an average distance of 6 inches from the lamps. Provision was made for turning the fruit during the exposure period to afford a uniform irradiation of all surfaces. The arrangement of the ultraviolet light equipment in relation to the grading machinery is illustrated in Fig. 1.

The intensity of the irradiation employed in these studies was determined by means of a meter which utilized a phototube consisting of a cadmium-magnesium alloy cathode enclosed in a thin Corex D glass bulb as the sensing element and an appropriate amplifier to measure the response due to energy that was primarily of the 2537A wave length. This equipment is described and illustrated by Luckiesh (3). Great variation in the light intensity was noted beneath the lamps. It ranged from 1,570 microwatts per square centimeter

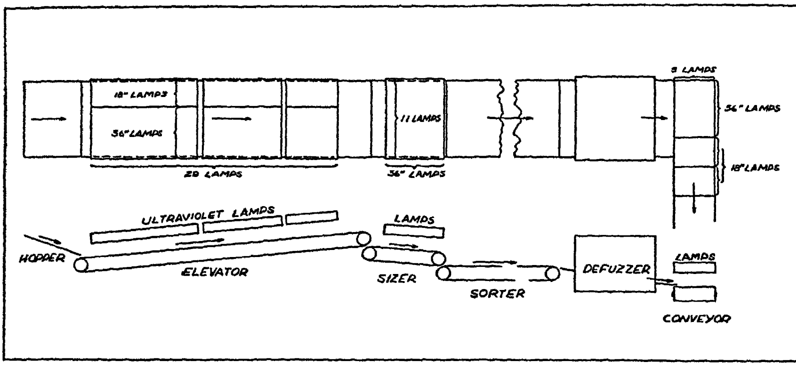


FIG. 1. The arrangement of lamps used for the commercial treatment of stone fruits with ultraviolet irradiation. The fruit was constantly turned while passing beneath the lamps and was exposed to the irradiation for a period of 35 seconds at a distance of 6 inches.

per second at the corners to 4,470 microwatts per square centimeter per second under the center of the battery of lamps. It was calculated that a surface moving beneath the lamps of the installation shown in Fig. 1 received a total dosage of 77,000 to 154,000 microwatts per square centimeter, depending upon whether it passed through areas of minimum or maximum light intensity.

The artificially inoculated fruit was treated with light in a stationary position so that the inoculated surface received the entire irradiation. Various exposure periods were used and the total dosage of ultraviolet irradiation was computed on the basis of time and intensity.

## METHODS AND RESULTS

Tests with naturally inoculated fruit included two varieties of peaches and nectarines and one variety of plums, handled in the normal commercial manner through the packing shed. Comparable and replicated lots of fruit were used, the treated fruit being passed over the grading equipment with the lights in operation and the untreated fruit being handled in a like manner but with the lights not in operation. Immediately following treatment the fruits were placed in clean boxes and held for observation. Various temperatures, as shown in the data summaries, were employed during the holding period, all of them more favorable for the growth of decay organisms than those normally encountered during the transit and marketing of these fruit. The infected fruits were removed whenever decay symptoms became evident; the causal organisms were not examined microscopically but the symptoms indicated the decays were primarily Rhizopus rot and brown rot.

The mean percentages of the original total number of fruit developing decay, together with the pertinent information of the 10 tests, are summarized in Table I.

TABLE I—EFFECT OF ULTRAVIOLET LIGHT IRRADIATION ON THE DECAY OF NATURALLY INOCULATED PEACHES, NECTARINES, AND PLUMS

| Variety | Date of Treatment | No. of Replications | No. of Fruits Per Replication | Days Held at 55 Degrees F | Days Held at 65 to 70 Degrees F | Per Cent of Total Fruit Decayed | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Treated | | Untreated | |
| | | | | | | Mean | S. D.* | Mean | S. D.* |
| | | | *Peaches* | | | | | | |
| Early Elberta | Jul 2, 1946 | 3 | 75 | 10 | 3 | 10.7 | 18.5 | 0.0 | — |
| | | | | 10 | 6 | 15.6 | 21.3 | 26.2 | 3.9 |
| Elberta. .... | Jul 23, 1946 | 3 | 75 | 8 | 0 | 0.9 | 1.6 | 31.5 | 18.7 |
| | | | | 8 | 1 | 10.6 | 11.4 | 48.0 | 16.3 |
| | | | | 8 | 5 | 12.9 | 11.1 | 75.1 | 21.4 |
| Elberta...... | Jul 30, 1946 | 3 | 75 | 10 | 0 | 0 4 | 2.4 | 9.8 | 16.9 |
| | | | | 10 | 5 | 7.6 | 7.3 | 29.3 | 28.2 |
| Elberta .... | Jul 10, 1947 | 5 | 50 | 0 | 14† | 2.0 | 2.8 | 1.2 | 1.8 |
| | | | | 0 | 21† | 14.8 | 4.1 | 17.2 | 5.0 |
| Elberta..... | Jul 16, 1947 | 10 | 50 | 0 | 14† | 8.6 | 5.9 | 7.4 | 6.9 |
| | | | | 0 | 21† | 34.8 | 14.3 | 34.4 | 5.3 |
| | | | *Nectarines* | | | | | | |
| John Rivers. | Jun 13, 1946 | 3 | 100 | 11 | 7 | 17.7 | 13.3 | 4.0 | 2.6 |
| | | | | 11 | 9 | 36.0 | 14.7 | 17.3 | 6.7 |
| Gower...... | Jul 7, 1946 | 3 | 100 | 0 | 5 | 40.3 | 16.1 | 37.0 | 36.1 |
| Gower....... | Jul 3, 1947 | 10 | 100 | 0 | 13† | 7.7 | 9.5 | 1.4 | 1.3 |
| | | | *Plums* | | | | | | |
| Santa Rosa... | Jun 21, 1946 | 3 | 100 | 10 | 11 | 2.3 | 1.5 | 1.0 | 1.0 |
| | | | | 10 | 17 | 19.7 | 7.1 | 36.0 | 8.9 |
| Santa Rosa... | Jun 27, 1946 | 3 | 100 | 12 | 7 | 1.7 | 0.6 | 1.0 | 1.0 |
| | | | | 12 | 14 | 4.7 | 2.9 | 4.3 | 3.2 |
| | | | | 12 | 17 | 22.0 | 11.5 | 42.3 | 0.5 |

*Standard deviation.
†Fruit held at approximately 80 degrees F.

Differences in the amount of decay occurring on fruit treated and not treated with ultraviolet irradiation were for the most part too small to indicate a beneficial effect of the irradiation. An exception was the test with peaches of July 23, 1946 in which decay development was considerably greater on untreated than on treated fruit of this test or on any fruit of the other tests. The extreme variability in the amount of decay developing as a result of natural infection, as shown by the standard deviations, was characteristic of practically all lots of fruit and it was not reduced by the ultraviolet irradiation.

An effect of the ultraviolet irradiation upon moisture loss from nectarines during the holding period was noted. The fruit used for these studies was selected as the least mature of that being packed for transcontinental shipment and hence the most likely to shrivel during the marketing period. The changes in fresh weight of fruit treated with light and that not treated are presented in Table II.

A highly significant decrease in the fresh weight of treated nectarines in comparison with those not treated occurred by the fourth day following exposure to the ultraviolet light. This effect was considerably more pronounced by the sixth day, and at this time a difference in the appearance of the treated and untreated fruit was very

TABLE II—EFFECT OF ULTRAVIOLET IRRADIATION ON MOISTURE LOSS BY GOWER NECTARINES, JULY 1947 (NINE REPLICATIONS OF 10 FRUITS EACH)

| No. Days | Loss as Percentage of Original Fresh Weight | | | Odds for Significance |
|---|---|---|---|---|
| | Treated Mean S. E. | Untreated Mean S. E. | Difference Mean S.E. | |
| 2 | 9.99 ±0.20 | 9.60 ±0.21 | 0.39±0.29 | 8:1* |
| 4 | 18.71 ±0.27 | 17.24 ±0.34 | 1.47±0.43 | 212:1** |
| 6 | 27.30 ±0.38 | 23.92 ±0 46 | 3.38±0.60 | 3332:1** |

*Not significant.
**Highly significant.

noticeable. The skin of all fruits treated with light had become shriveled and deeply wrinkled, whereas only a third of the untreated fruits were in this condition. Although weights of the more mature nectarines were not recorded, inspection of the fruit that was held for observation of decay showed a similar although less pronounced change in appearance due to the light treatment in comparison with untreated fruit.

Differences in fresh weight between treated and untreated peaches did not occur during the holding period, nor were differences in the amount of shriveling detected in these or in peaches held for the observation of decay development.

Ripe Elberta peaches were artificially inoculated with Rhizopus spores and exposed to a single 18-inch ultraviolet lamp at a distance of 4 inches for periods of time up to 10 minutes. The peaches were inoculated by removing a small piece of skin from the peach and applying spores to the smooth exposed surface of flesh with a camel's hair brush which had been brushed across a sporulating growth of Rhizopus on peach fruits. The inoculated peaches were irradiated for periods of ½ to 10 minutes and then held at 75 degrees F for observation. The amount of infection that developed following 2, 3, and 4 days' incubation is shown in Table III.

TABLE III—INFECTION OF ELBERTA PEACHES ARTIFICIALLY INOCULATED WITH RHIZOPUS SPORES AND EXPOSED TO ULTRAVIOLET LIGHT

| Minutes Exposed to Light* | Total Dosage of Radiation in Microwatts Per Sq Cm | Per Cent of Total Fruit With Rhizopus Rot Infection After Incubation at 75 Degrees F For: | | |
|---|---|---|---|---|
| | | 2 Days | 3 Days | 4 Days |
| 0 | 0 | 90 | 100 | 100 |
| 0.5 | 45,000 | 60 | 80 | 90 |
| 1 | 90,000 | 70 | 80 | 80 |
| 2 | 180,000 | 70 | 70 | 80 |
| 3 | 270,000 | 30 | 50 | 60 |
| 5 | 450,000 | 70 | 80 | 100 |
| 10 | 900,000 | 10 | 30 | 70 |

*Single 18-inch lamp at a distance of 4 inches.

Two tests were also made on peaches of the Lovell variety which were artificially inoculated and subjected to various dosages of ultraviolet irradiation. These fruits were inoculated by applying a water suspension of Rhizopus spores and mycelium to a smooth tangential cut. The inoculated surface of the peaches was exposed to

ultraviolet irradiation at a distance of 6 inches beneath a battery of five 36-inch lamps with reflectors, for periods up to 6 minutes. Immediately following the light treatment, the fruit was placed in an incubation chamber and held at 90 degrees F and approximately 80 per cent relative humidity for 48 hours. The percentages of fruit showing infection with Rhizopus are summarized in Table IV. Each lot treated consisted of 20 peaches.

TABLE IV—INFECTION OF LOVELL PEACHES ARTIFICIALLY INOCULATED WITH RHIZOPUS SPORES AND EXPOSED TO ULTRAVIOLET LIGHT

| Minutes Exposed to Light* | Total Dosage of Radiation in Microwatts Per Sq Cm | Per Cent of Total Fruit With Rhizopus Rot Infection After Incubation at 90 Degrees F for 48 Hours | |
|---|---|---|---|
| | | Test No. 1 | Test No. 2 |
| 1 | 252,000 | 70 | 100 |
| 2 | 504,000 | 50 | 95 |
| 3 | 756,000 | 65 | 90 |
| 4 | 1,008,000 | 50 | 75 |
| 5 | 1,260,000 | 55 | 65 |
| 6 | 1,512,000 | — | 35 |

*Battery of five 36-inch lamps mounted in reflectors 5 inches in width, at a distance of 6 inches.

Even the maximum irradiation of the freshly cut and inoculated surfaces of Elberta and Lovell peaches failed to arrest decay. However, in all of the tests a marked decrease in the amount of infection occurring in the first 48 hours following treatment was noticeable as the length of the periods of irradiation was increased.

## DISCUSSION

The treatment of peaches, nectarines, and plums with ultraviolet light in these tests was of doubtful value. In the single test in which the irradiation seemed to decrease decay of peaches, over 10 per cent of the treated fruit had decayed within 1 day after being removed from refrigerator car temperatures. Ultraviolet irradiation, therefore, as used in these tests did not prove to be a reliable or commercially feasible means of preventing decay in peaches, plums, and nectarines. The rapid loss of moisture from the nectarines following ultraviolet irradiation indicated that injury might be expected on some fruits, particularly if high intensities and long exposures were used to increase the effectiveness. Dehydration of the fruit was indicated early in the holding period by loss in weight, and a little later by the shriveled appearance of the fruit. The ultraviolet irradiation apparently was injurious to the epidermis.

Santa Rosa plums were highly resistant to invasion by fruit-rotting organisms and needed no treatment. Untreated and treated lots remained practically free from decay after a 10- to 12-day "shipping" period at 55 degrees F. Thereafter, as decay developed, it was of similar amount in both lots.

The results obtained by English and Gerhardt (1) on the amount of ultraviolet irradiation needed to kill spores of *Rhizopus* sp., indicate that the dosages used in these tests on naturally-inoculated fruit were not sufficient to kill the organisms involved. In their

studies, spores were seeded onto nutrient agar in petri dishes and exposed at a distance of 18 inches from a battery of 30-watt lamps with reflectors, for periods varying from 30 seconds to 5 minutes. The maximum intensity at a distance of 18 inches from a similar battery of lamps employed for the treatment of peaches, nectarines, and plums was found to be approximately 2,200 microwatt-seconds, or about one-half the intensity at a distance of 6 inches from the lamps. On this basis, the total dosage necessary to kill 96.0 per cent of the spores would be 660,000 microwatts per square centimeter of surface (2,200 microwatts per second for 5 minutes). Assuming that the peaches, nectarines, and plums were treated with the maximum irradiation available (154,000 microwatts), they would have received approximately one-fourth of the amount lethal to a large number of spores on agar. Since the fruit was constantly turned during the treatment period and often received irradiation of less than maximum intensity while passing beneath the lamps, it is obvious that any given fruit surface received an extremely small portion of a lethal dosage of ultraviolet irradiation.

The length of time that fruit may be exposed to ultraviolet radiation during commercial handling operations is physically limited by the space available for lights and the practical speed for operation of the packing plant. Fig. 1 shows that about all the space available for lights was used and slower handling of the fruit to give longer exposures and hence, more lethal dosages would not be economically feasible. Even were longer exposures of the fruit to irradiation possible, the tests with inoculated fruit indicate that it would not be possible to attain complete control of decay. The irradiation of the inoculated surface of Lovell peaches for 5 minutes was nearly twice the dosage that was lethal to Rhizopus spores, but still 55 and 65 per cent of the fruits became infected after incubation for 48 hours at 90 degrees F, and 35 per cent were infected even when exposure period was lengthened to 6 minutes in one of the tests.

It has been suggested by English and Gerhardt (1) that the failure of ultraviolet light to control cherry rots was due, not to the inability of the light to kill the organisms when given the proper intensity, wave length, and length of exposure, but to the inability of the ultraviolet rays to reach all of the organisms. Fulton and Coblentz (2) when unable to control blue mold of oranges with ultraviolet irradiation in 1929, attributed the failure partly to the inability of the ultraviolet rays to penetrate to the spores or mycelium that may be hidden within cracks or apertures of the fruit skin or shaded by other spores and mycelium.

## Summary

Tests with naturally inoculated stone fruits were made to determine the efficacy of ultraviolet light treatment in reducing the subsequent development of decay.

Ultraviolet irradiation of peaches with commercial packing shed equipment reduced decay in only one of five tests conducted. Nec-

tarines and plums showed no reduction in decay from the ultraviolet irradiation.

Exposure of nectarines to ultraviolet light resulted in injury in the form of a rapid dehydration and shriveling of the epidermis.

The treatment of artificially inoculated peaches for periods up to 6 minutes retarded decay, but did not completely inhibit its development.

## Literature Cited

1. English, Harley, and Gerhardt, Fisk. The effect of ultraviolet radiation on the viability of fungus spores and on the development of decay in sweet cherries. *Phytopath.* 36: 100–111. 1946.
2. Fulton, H. R., and Coblentz, W. W. The fungicidal action of ultraviolet radiation. *Jour. Agr. Res.* 38: 159–168. 1929.
3. Luckiesh, Matthew. Applications of Germicidal, Erythemal and Infrared Energy. D. Van Nostrand Co., Inc., New York, N. Y. 1946.

# Pretreatment Of Frozen Apples For Baking

By Irvin Kilby and H. D. Brown, *Ohio State University, Columbus, Ohio*

There is a demand for apples prepared for baking. Frozen cored apples seem to provide this demand. Such apples must be able to withstand the vigorous freezing as well as the baking processes and at the same time maintain their flavor and color.

In this study attempts to achieve these ends were made by additions of calcium chloride, ascorbic acid, and by the withdrawal of air and its subsequent replacement with sucrose and sucrose containing calcium chloride ascorbic acid, and "red hots". Different variations were used in order to detect varietal differences.

Considerable attention was directed toward the exclusion of air first because the oxygen of the air is essential for discoloration, and second because the withdrawal of air facilitates the penetration of solvents. After the air is evacuated the solvents are allowed to replace the air while the apples are submerged and thus not exposed to air.

It was soon discovered that any solution or solutions having an osmotic value of less than that of the apple juice would cause the skin of the apple to crack. By using distilled water to displace the extracted air the apples completely disintegrated (see Fig. 1). It is necessary to use sugar solutions of 15 per cent brix or more to completely prevent this bursting of the cells. If 30 per cent brix syrup is used slight shriveling results.


Fig. 1. Apples labeled A treated under vacuum in a 30 per cent sucrose solution. Apples labeled B treated under vacuum in water. Note the disintegration of apples in the water after the release of the vacuum.

Several tests were made to determine the most effective method of removing the air from apples. Vacuums of 25 to 27 inches required from 3 to 4 hours to remove most of the air (as indicated by bubbles arising from the skin, stem and calyx ends) from medium sized apples at room temperatures (70 to 75 degrees F) and it apparently requires even longer to be sure the sucrose has penetrated all the tissues after the vacuum is removed. At 28 to 29 inches vacuum the water cools rapidly to approximately 44 degrees F and air removal seems to be retarded. The high vacuum is impractical if the fruits are submerged because of the rapid evaporation. Some means of adding the solution after the air had been withdrawn and before the vacuum is released might be feasible. However, such a method was not perfected. The most practical method of removing air so far discovered includes the simultaneous heating while the product is subjected to a vacuum of 24 to 26 inches. Though all possible temperature and vacuum combinations have not been tested a temperature of 130 degrees and a vacuum of 26 inches proved to be satisfactory. Even at this temperature it requires nearly an hour to extract most of the air and an equal length of time for the solution to penetrate the tissue. If at the end of the treatment the apples sink in a 20 per cent sucrose solution, it is sufficient evidence that penetration has been sufficient to achieve practical results. In these tests a 12-inch Pyrex dessicator and a Mojonnier Brothers Company vacuum pump were used.

Other means of measuring the degree of penetration include taste, the appearance of water soaked regions, and the use of colored solutions. "Red Hots" were used in several tests. The penetration of the color from "Red Hots" is almost entirely from the core and none through the skin. This is in striking contrast to the penetration of sucrose solutions as measured by taste and the appearance of water-soaked areas. As apples are subjected to a vacuum while submerged in a liquid media, it is possible to see air bubbles arise from almost all areas of the skin and from the stem and calyx ends. Much air escapes from the cut surfaces of cored apples. Air is liberated in the form of bubbles before bubbles of water vapor are formed. Later it is, of course, difficult to distinguish between air and water vapor bubbles. Apparently the failure of the color from "Red Hots" to penetrate the skin indicates that the skin acts as a semi-permeable membrane, which prohibits the passage of the pigment. Further study of this phenomenon might lead to important conclusions.

Some ripe plums (variety unknown) with a refractive index of approximately 1.3537 indicating a sugar content of less than 13.7 per cent were included in several tests in which 20 brix and 30 brix sucrose solutions were used. In all instances the flavor after treatment was distinctly more sour to the taste. This again may be due to the influence of a semi-permeable membrane. One plum exploded, that is, the skin burst in a 30 brix solution. This was unexpected and remains unexplained.

Attempts to secure more rapid removal of air and more rapid

penetration of the sucrose solutions were made by pricking the apples with needles. The punctures extended through the skin and flesh to the area where the core was removed. This technique was somewhat effective but more data will need be secured before it can be recommended. Fifty punctures through small (1½ inches in diameter) Red Astrachan apples failed to result in a uniform coloring by "Red Hots" (30 brix), although the channel made by the needle punctures could be readily identified by the red color which did not penetrate the tissue much beyond the hole made by the needle.

Rome Beauty, Stayman-Winesap, Jonathan, Golden Delicious and Delicious apples were used in an attempt to evaluate their adaptability for frozen apples to be used for baking. The only practical index of difference seemed to be appearance and taste. The differences in appearance were recorded by photographs. Pressure tests readings were of no value. The penetrometer used was made by the Precision Scientific Company of Chicago. Plungers of various shapes were tried. The plunger tip that seemed to offer the best possibility of accurate measurements was conical in shape and tapered from a point of .1 mm in diameter to 2.1 mm at a depth of 3.3 mm. In making the measurements the plunger was dropped a definite distance from the top of the baked apple and the penetration recorded in millimeters.

Table I shows the results with Rome Beauty, Stayman Winesap and Jonathan apples. Obviously, the differences are not significant. The type of pentrometer used by Esselen *et al* was not available.

TABLE I—PENETROMETER READINGS ON THREE VARIETIES OF BAKED APPLES (MEASUREMENTS WERE TAKEN FROM CALYX END OF APPLE)

| Control | | 1 Per Cent Calcium Chloride | |
|---|---|---|---|
| Inside* | Outside** | Inside | Outside |
| *Rome Beauty* | | | |
| 290 | 302 | 275 | 280 |
| 295 | 310 | 270 | 275 |
| 310 | 295 | 290 | 277 |
| 298 | 290 | 300 | 310 |
| 320 | 315 | 288 | 295 |
| 299 | 320 | 298 | 290 |
| Average 302 | 305 | Average 287 | 288 |
| *Stayman-Winesap* | | | |
| 310 | 292 | 280 | 285 |
| 290 | 280 | 285 | 292 |
| 270 | 310 | 280 | 297 |
| 281 | 303 | 260 | 285 |
| 273 | 310 | 275 | 260 |
| Average 285 | 299 | Average 276 | 284 |
| *Jonathan* | | | |
| 322 | 326 | 305 | 355 |
| 310 | 318 | 320 | 362 |
| 332 | 295 | 330 | 341 |
| 325 | 282 | 311 | 370 |
| 305 | 258 | 300 | 345 |
| Average 319 | 296 | Average 313 | 355 |

*Inside refers to area next to center of apple.
**Outside refers to the area next to the peel.

Neither was a satisfactory pressure tester found. After several attempts with an improvised pressure tester this method was discarded.

The effects of different concentrations of calcium chloride in 30 per cent sucrose solutions on five varieties of apples are shown in Table II. In order to better evaluate varietal differences the apples were subjected to a vacuum of from 24 to 25 inches for only 10 minutes, after which they were left submerged for only 5 minutes. After treatment the apples were frozen in a 30 per cent sucrose solution at —30 degrees F and stored at 0 degree F. After various periods in the 0 degree F freezer the apples were baked for 40 to 50 minutes at 350 degrees F in an electric rotary oven. Typical results are shown in Table II. In this particular test all treated apples produced an acceptable baked product. At the time of processing December 8, 1947, the apples had the following pressure test readings (4) Golden Delicious 15.5, Red Delicious 16.6, Stayman Winesap 19.0, Jonathan 19.3, and Rome Beauty 20.5.

TABLE II—FIRMNESS RATINGS ON CALCIUM TREATED BAKED APPLES (APPLES TREATED DECEMBER 8, 1947; APPLES BAKED APRIL 26, 1948)

| Variety | Control | Concentration of Calcium Chloride (Per Cent) | | | |
|---|---|---|---|---|---|
| | | 0.1 | 0.2 | 0.5 | 1 |
| Stayman-Winesap | 1 | 1 | 1 | 3 | 4 |
| Red Delicious | 1 | 1 | 1 | 3 | 4 |
| Golden Delicious | 0 | 0 | 1 | 1 | 2 |
| Rome Beauty | 1 | 1 | 1 | 1 | 2 |
| Jonathan | 0 | 0 | 1 | 2 | 4 |

0—Soft 3—Medium firm 5—Firm

Another test made from apples processed February 14, 1948, when the pressure test readings of all varieties had decreased about two points still showed that all varieties were effectively firmed by the calcium-chloride vacuum treatment. However, apples treated on March 12, 1948, when the readings had declined still further were not all sufficiently firmed. At time of treatment the pressure test readings were as follows: Golden Delicious 8, Red Delicious 8.2, Rome Beauty 15, Stayman Winesap 12, and Jonathan 10. The firmness ratings are shown in Table III. From this table it is evident that some apples with pressure test readings of 8 and 8.2 cannot be satisfactorily hardened with calcium chloride so that they are suitable for baking. The varieties were rated for flavor and texture in the following order: Stayman-Winesap, Jonathan, Rome Beauty, Golden Delicious, and Red Delicious. Rome Beauty was graded down because of its flat flavor.

One test was made to see if the conventional dip method (2) would be effective for firming whole apples. Stayman-Winesap, Red Delicious, and Jonathan varieties were not affected and the firming of Golden Delicious and Rome Beauty was so slight as to be of no practical importance.

An attempt was made to determine how much calcium chloride was absorbed by determining the weight of apples before and after

TABLE III—FIRMNESS RATINGS ON CALCIUM TREATED BAKED APPLES (TREATED MARCH 12, 1948; BAKED MAY 5, 1948)

| Variety | Control | Concentrations of Calcium Chloride (Per Cent) | | | |
|---|---|---|---|---|---|
| | | 0.1 | 0.2 | 0.5 | 1 |
| Stayman-Winesap | 0 | 2 | 2.5 | 3 | 3.5 |
| Golden Delicious | 0 | 1 | 1 | 1 | 1 |
| Rome Beauty | 0 | 3 | 3.5 | 3.5 | 4 |
| Jonathan | 0 | 3 | 4 | 4 | 4 |
| Red Delicious | 0 | 1.5 | 1.5 | 1.5 | 1.5 |

0—Soft 3—Medium firm 5—Tough

treatment. With the 10-minute vacuum followed by the 5-minute submergement in 1 per cent calcium chloride the greatest increase in weight was .1 pound for 2.5 pounds of apples or .0004 per cent calcium chloride. This is for under the tolerance of .07 per cent anhydrous calcium chloride as recently permitted by the Pure Food and Drug Administration.

## LITERATURE CITED

1. ESSELEN, W. B. JR., HART, W. J. JR., and FELLERS, C. R. Further studies on the use of calcium chloride to maintain firmness in canned and frozen apples. *Fruit Prod. Jour. and Food Mfg.* pp. 356, 357. August 1947.
2. ESSELEN, W. B. JR., RASMUSSEN, C. L., and FELLERS, C. R. Prepared fresh McIntosh apple slices. *Fruit Prod. Jour. and Food Manufacturer,* pp. 276–279. June 1948.
3. KERTESZ, Z. I. The effect of calcium on plant tissue. *The Canner* No. *7*: 26, 27. 1939.
4. MAGNESS, J. H. Fruit testers and their practical application. *U.S.D.A. Cir.* 627. 1941.

# Jellies Produced From Steam Condensate From Apple Blancher[1]

By Lyle L. Davis, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

Peeled, cored apple slices or rings lose from 5 to 9 per cent weight when steam-blanched in preparation for commercial freezing. While browning of apples, by enzymic action during preparation or while frozen, may be prevented by other methods, such as by treatment with sulfur dioxide, ascorbic acid, or by vacuumizing in salt water or syrup, steam-blanching is used in commercial freezing plants in Virginia and widely elsewhere. That portion lost from the apple in the steam-blancher and the steam condensate has been discarded, even though commercial processors recognize that there is a loss of flavor when apples are thus blanched, and that some of this flavor is in the drip from the blancher. The investigations reported in this paper were to determine whether this liquid previously wasted could be made into an apple jelly with flavor and color characteristic of the variety.

## Materials and Methods

The fresh apples, as they came from cold storage, ranged in color from green-yellow of the Albemarle Pippin to as much as 50 per cent red in York Imperial, Black Twig, and Stayman Winesap. The fruit was firm to very firm, and varieties were processed in order of maturity.

From 840 to 1000 pounds of sliced apples per hour were blanched in a steam-blancher, and blanching time varied from 2 to 3 minutes as necessary to inactivate the enzymes. The amount of condensate varied from 30 to 60 gallons per hour. Samples of this condensate from the discharge pipe on the steam-blancher, at a temperature of 190 to 200 degrees F, were collected at various dates from October 30, 1946, to February 6, 1947, in clean glass containers, and stored at 33 to 34 degrees F until used in these jelly experiments in January, February, and March 1948. Since the condensate had a pH of 3.2 to 3.7, and was packed in sealed containers at pasteurization temperature, no mold growth occurred in storage.

The condensate of each of the apple varieties was divided into three lots. In lot 1, the condensate was used as obtained from the blancher; in lot 2, the condensate was concentrated by boiling to approximately two-thirds of its original volume; and in lot 3, the condensate was concentrated to approximately one-third of its original volume. Each of the three lots was divided into two samples. In one sample, the pH was adjusted with citric acid to 3.0, while the other retained the original pH or as modified by concentration. The condensate from York Imperial before concentration had a pH of 3.7 and a Brix of 3.5; Stayman Winesap had a pH of 3.5 and a Brix of 5.0; Albemarle

[1]Contribution from Department of Horticulture, Fruit and Vegetable Processing and By-Products Section, Virginia Polytechnic Institute.

Pippin had a pH of 3.2 and a Brix of 5.0; Black Twig had a pH of 3.6 and a Brix of 4.0. Sugar jellies of 65 degrees Brix were made from each sample using a commercial liquid apple pectin as recommended by the manufacturer.

After all jelly samples had been prepared, a tasting panel of six from the Department of Home Economics and the Extension Service scored each jelly upon a standard of 100.0. An average score for each jelly was determined.

## Results

Good quality jellies were produced from the condensate obtained from each of the varieties: York Imperial, Stayman Winesap, Albemarle Pippin, and Black Twig apples, as they were steam-blanched in a commercial frozen food plant in Virginia.[2] It will be observed (Table I) that these jellies were scored relatively high (87 to 93), and that no commercial jelly was used for comparison. The tasting panel was checked to determine if scoring could be duplicated. Samples 7, 8, 9, 10, 11 and 12 were duplicates of samples 25, 26, 27, 28, 29 and 30. The judges were unaware that these lots were duplicated, but the average score of each lot was 88, which indicated dependable results.

The pH of the condensate varied with the variety, being lowest with the Albemarle Pippin and highest with the York Imperial. Furthermore, the pH of the condensate concentrated by boiling generally tended to be higher, especially with the Albemarle Pippin. This may indicate loss of volatile acids.

## Discussion

This experiment demonstrated that a jelly possessing a natural color and a pleasing natural apple flavor could be made from the condensate of a steam apple blancher, used in preparing fruit for freezing. Each jelly possessed a flavor and color characteristic of the variety blanched, and since the solid particles of apple, in suspension in the condensate, as it came from the blancher, had settled out in storage, a clear attractive jelly resulted. Good jelly was made with the range of pH 3.0 to 4.3 (1). Thus a means is provided for the commercial utilization of material previously wasted in the steam-blanching of apples to be frozen.

## Summary

1. Condensate was collected from the discharge line of a commercial blancher, in a frozen apple line, as York Imperial, Stayman Winesap, Albemarle Pippin, and Black Twig apple slices were successively blanched.

2. These original condensates varied depending upon the variety from pH 3.2 to 3.7 and in degrees Brix from 4.0 to 5.0.

3. Concentration of the condensate to approximately one-third of

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[2]These studies were made through the cooperation of the Crozet Cold Storage Corporation, Crozet, Virginia.

TABLE I—SUGAR JELLIES (65 DEGREES BRIX) FROM APPLE CONDENSATE

| Sample No. | pH* | Concentration Per Cent Original Value | Jelly Score† |
|---|---|---|---|
| | | *York Imperial* | |
| 1 | 3.7 | 100 | 89 |
| 2 | 3.0 | 100 | 93 |
| 3 | 3.7 | 100 | 90 |
| 4 | 3.0 | 100 | 87 |
| 5 | 3.7 | 100 | 88 |
| 6 | 3.0 | 100 | 87 |
| | | *Stayman Winesap* | |
| 7 | 3.5 | 100 | 89 |
| 8 | 3.0 | 100 | 91 |
| 9 | 3.5 | 71 | 90 |
| 10 | 3.0 | 71 | 87 |
| 11 | 3.8 | 42 | 89 |
| 12 | 3.0 | 42 | 85 |
| | | *Albemarle Pippin* | |
| 13 | 3.2 | 100 | 88 |
| 14 | 3.0 | 100 | 90 |
| 15 | 4.3 | 63 | 88 |
| 16 | 3.0 | 63 | 88 |
| 17 | 4.2 | 33 | 93 |
| 18 | 3.0 | 33 | 90 |
| | | *Black Twig* | |
| 19 | 3.6 | 100 | 89 |
| 20 | 3.0 | 100 | 91 |
| 21 | 3.6 | 67 | 91 |
| 22 | 3.0 | 67 | 91 |
| 23 | 3.6 | 22 | 90 |
| 24 | 3.0 | 100 | 90 |
| | | *Stayman Winesap* | |
| 25 | 3.5 | 100 | 90 |
| 26 | 3.0 | 100 | 87 |
| 27 | 3.5 | 67 | 91 |
| 28 | 3.0 | 67 | 87 |
| 29 | 3.6 | 25 | 88 |
| 30 | 3.0 | 25 | 87 |

*The pH of the even sample numbers was adjusted to a pH of 3.0 with citric acid.
†Each jelly automatically received a score of 10 for "Appearance of Jar" so that only the jell characteristics would be considered. Otherwise, the jellies were scored according to the following score card:

| | |
|---|---|
| Appearance: natural color, clear, no crystals | 25 |
| Consistency: holds shape, tender, quivery | 30 |
| Flavor and taste: natural, pleasing | 35 |
| Appearance of jar: appropriate, well covered | 10 |
| | 100 |

the original volume, especially with the Albemarle Pippin, tended to result in a higher pH, possibly by loss of volatile acids.

4. These condensates were made into a 65 degrees Brix sugar jelly; (a) without concentration; (b) concentration to two-thirds of original volume; and (c) concentration to one-third of original volume.

5. A good flavored apple jelly, clear and of variable color, ranging from a light tint of yellow with Albemarle Pippin to pink and deep red, depending upon the redness of the variety and the degree of concentration, was prepared.

6. It is believed that jelly superior to that of "cider jelly" can be made by utilizing the condensate from steam-blanching lines in frozen apple processing, and that such jelly would find much appeal in the

commercial trade. At the present time, such jellies would have to be labeled as "spreads", pending a possible change in the definition of standards of the Pure Food and Drug Administration.

## Literature Cited

1. Tarr, L. W. Fruit jellies, the role of acids. *Del. Agr. Exp. Sta. Bul.* 134. 1923.

# Chromosome Numbers of Apple Varieties and Sports II[1]

By JOHN EINSET and BARBARA IMHOFE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

IN AN earlier paper (7) chromosome counts were reported for a number of apple varieties and sports. The varieties and color sports examined were all found to be diploids with 34 chromosomes or triploids with 51 chromosomes. Four large-fruited sports of diploid varieties were found to be periclinal chimeras made up of diploid and tetraploid tissues.

## MATERIALS AND METHODS

The materials for study were for the most part collected from the Station orchards at Geneva, New York. Some of the large-fruited sports were collected and sent in by growers. Twigs or branches of the trees were taken in February and March and placed in water. After several days in a heated greenhouse leaf and flower buds were collected, fixed in CRAF (13) and imbedded in paraffin. Staining was done with Crystal Violet after bleaching in potassium permanganate and oxalic acid.

## OBSERVATIONS

In Table I the varieties are grouped according to chromosome number as diploids ($2n = 34$), triploids ($3n = 51$) or diploid-tetraploid chimeras. The present location of each sort, together with the original source and date of accession is included in order that the exact source of the cytological material may be referred to in the future if the occasion should arise.

*Diploids:*—Many of the varieties listed have previously been assumed to be diploid on the basis of the plump appearance and good germination of the pollen, the breeding behavior of the sort when used in crossing and also because of the full seed complement of the fruit. However, these varieties were checked in a routine survey and are included in the table in those instances when we had no literature reference to a published chromosome count.

*Diploid-Tetraploid Chimeras:*—In our first report (7) we listed four different large-fruited sports of apples that were found to be periclinal chimeras. Six additional, similar sports are here listed. These chimeras have been found to be of three distinctive types differing with respect to the relative amounts of diploid and tetraploid tissue. A complete description of these types has been published (2,6).

Type 1 (one layer diploid) is predominantly tetraploid with only an epidermis of diploid cells. All internal tissues are made up of cells with the tetraploid number of 68 chromosomes. Sports of this type breed like tetraploid apples and produce tetraploid seed following self pollination.

[1]Journal Paper No. 787, New York State Agricultural Experiment Station, Geneva, N. Y., December 3, 1948.

TABLE I—CHROMOSOME COUNTS OF APPLE VARIETIES AND SPORTS

| Variety | Source of Trees and Date of Original Accession | Location in Station Orchards (1948) | Remarks |
|---|---|---|---|
| | *Diploids* | | |
| Alton (New York No. 4588) | E. McIntosh × (Red Canada × Y. Trans.), introduced 1938 | 1–14–19 | |
| Bayfield | Clinton Falls Nursery Co., Owatonna, Minn. 1921 | 21–10–23 | |
| Bonita | Luther Burbank, Santa Rosa, Cal. 1919 | 21–10–10 | |
| Chinook | C. A. Hansen, Brookings, So. Dak. 1927 | 17–5–10 | |
| Climax | U.S.D.A., Washington, D. C., S.P.I. 43154, 1923 | 21–6–17 | |
| Collamer | J. B. Collamer, Hilton, N. Y. 1901 | 17–2–16 | Red sport of Twenty Ounce, reported diploid (11) |
| Cortland (New York No. 79) | Ben Davis × McIntosh, introduced 1915 | 17–2–17 | Suspected diploid (8, 12) |
| Coulon | U.S.D.A., Glenn Dale, Md., F.P.I. 89799, 1939 | 17–18–12 | |
| Crimson | Luther Burbank, Santa Rosa, Cal. 1919 | 21–10–16 | |
| Delwine | W. Downs, Yakima, Wash. 1925 | 17–5–13 | |
| Duke of Devonshire | Geo. Bunyard & Co., Maidstone, Eng. 1928 | 17–6–14 | |
| Early McIntosh (New York No. 1022) | Yellow Transparent × McIntosh, introduced 1923 | 17–2–30 | |
| Easter Orange | Geo. Bunyard & Co., Maidstone, Eng. 1928 | 17–6–18 | |
| Ellison Orange | Geo. Bunyard & Co., Maidstone, Eng. 1928 | 17–6–22 | |
| Excelsior (crab) | W. & T. Smith Co., Geneva, N. Y. 1911 | 17–1–23 | |
| Fanny | Ellwanger & Barry, Rochester, N. Y. 1888 | 17–2–38 | |
| Florence (crab) | Stark Bros., Louisiana, Mo. 1896 | 17–1–31 | |
| Folwell | State Fruit Breeding Farm, Excelsior, Minn. 1924 | 21–13–9 | |
| Giant Jeniton | Stark Bros., Louisiana, Mo. 1914 | 12–11–13 | |
| Golden Delicious | Stark Bros., Louisiana, Mo. 1916 | 17–2–39 | Originally Stark No. 16 |
| Goldo | C. A. Hansen, Brookings, S. Dak. 1927 | 17–5–16 | |
| Goodhue | Wedge Nurseries, Albert Lea, Minn. 1921 | 21–20–19 | |
| Greendale (New York No. 4793) | McIntosh × Lodi, introduced 1938 | 1–14–29 | |
| Gurney Seedless (crab) | Gurney Seed & Nursery Co., Yankton, S. D. 1930 | 17–1–27 | |
| Hollow Log | Valdesian Nurseries, Bostic, No. Car. 1928 | 17–6–26 | |
| Hopa (crab) | M. A. Blake, New Brunswick, N. J. 1932 | 17–1–22 | |
| Hume | Vineland Station, Ontario, Canada, 1929 | 21–5–16 | |
| Indo | Aomori Exp. Sta., Kuroiski, Aomori-Ken, Japan 1936 | 21–4–16 | |
| Jersey Black | Monroe County Nurseries, Rochester, N. Y. 1900 | 17–2–45 | |
| Joyce | E. D. Smith & Sons, Ltd., Winona, Ont., Canada 1927 | 17–5–20 | |
| Justice | D. S. Harris, Williamsburg, Va. 1919 | 21–10–6 | |
| Kendall (New York No. 3616) | Zusoff × McIntosh, introduced 1932 | 17–2–20 | |
| Knowles Blueblood | E. E. Gage, Canton, Mass. 1923 | 21–12–20 | |
| La Salle | Stone & Wellington, Toronto, Ontario, Can. 1927 | 17–5–21 | |
| Lady Seedling | Geo. Bunyard & Co., Maidstone, Eng. 1928 | 17–6–32 | |
| Large Yellow Siberian (crab) | Ellwanger & Barry, Rochester, N. Y. 1907 | 17–1–35 | |
| Laxton Superb | Laxton Bros. Nurseries, Bedford, Eng. 1928 | 17–6–36 | |
| Liveland Raspberry | Stark Bros., Louisiana, Mo. 1912 | 17–3–6 | |
| Lodi (New York No. 2581) | Montgomery × Yellow Transparent, introduced 1924 | 17–6–37 | |
| Martha (crab) | Scions received about 1888 | 17–1–37 | |
| Milan | Hopedale Nursery Co., Hopedale, Ill. 1926 | 17–4–47 | |
| Milton (New York No. 1040) | Yellow Transparent × McIntosh, introduced 1923 | 21–16–17 | Assumed to be diploid (12) |
| Minnehaha (Minn. No. 300) | State Fruit Breeding Farm, Excelsior, Minn. 1924 | 17–5–23 | |
| Newfane (New York No. 2236) | Deacon Jones × Delicious, introduced 1927 | 17–3–22 | |
| Newman | C. P. Newman, Ville Lasalle, Que., Canada 1924 | 1–13–30 | Not same as Newman of Beach (1) |
| Niobe | E. D. Smith & Sons, Ltd., Winona, Ont. ,Canada 1927 | 17–5–29 | |
| No Blow Seedless | U.S.D.A., Washington, D. C., S.P.I. 24626 1909 | 17–3–23 | |
| No Calyx (crab) | Experiment Station, [illegible] | | |

| | | | |
|---|---|---|---|
| Ogden (New York No. 3609) | Zusoff × McIntosh, introduced 1928 | 17–7–38 | |
| Orleans (New York No. 2078) | Deacon Jones × Delicious, introduced 1924 | 17–3–31 | |
| Oswego (New York No. 57) | Sutton × Northern Spy, introduced 1915 | 17–3–33 | |
| Piotosh (crab) | Andrews Nursery Co., Faribault, Minn. 1942 | 17–1–48 | |
| Red Jacket (New York No. 11933) | Malus niedzwetzkyana × M. atrosanguinea, introduced 1939 | 1–9–39 | An ornamental form |
| Red Rome | L. S. Clifton, Memphis, N. Y. 1921 | 17–3–39 | Red sport of Rome |
| Red St. Lawrence | L. F. Peck, Unadilla, N. Y. 1927 | 17–3–41 | Supposedly red sport of St. Lawrence |
| Redfield (New York No. 4840) | Wolf River × M. niedzwetzkyana, introduced 1938 | 1–8–12 | An ornamental crab |
| Redflesh (crab) | N. E. Hansen, Brookings, So. Dak. 1929 | 17–1–25 | |
| Redford (New York No. 4876) | Wolf River × M. niedzwetzkyana | 1–8–17 | An ornamental crab |
| Reliance | W. A. Baker, Wolcott, N. Y. 1920 | 21–11–26 | |
| Rhoda | Wedge Nursery, Albert Lea, Minn. 1927 | 17–5–35 | |
| Richared | Columbia and Okanogan Nursery Co., Wenatchee, Wash. 1928 | 17–5–38 | Red sport of Delicious |
| Rones (crab) | Experiment Station, Lincoln, Neb., S.P.I. 19673 1914 | 21–6–6 | |
| Russian White | C. A. Hansen, Brookings, So. Dak. 1927 | 17–5–40 | |
| St. Lawrence | V. S. de Rocha, Bristol, R. I. 1934 | 17–13–44 | Pollen germination good (8) |
| Saratoga (New York No. 96) | Ben Davis × Green Newtown, introduced 1914 | 17–4–5 | |
| September (crab) | P. M. Gideon, Excelsior, Minn. 1888 | 17–1–40 | |
| SeeandO Winesap | Columbia & Okanogan Nursery, Wenatchee, Wash. 1932 | 17–8–28 | Supposedly red sport of Winesap |
| Sixteen Ounce | F. D. Reed, Geneva, N. Y. 1927 | 17–5–41 | |
| Starking | Stark Bros., Louisiana, Mo. 1926 | 17–4–9 | Red sport of Delicious |
| Surprise | N. E. Hansen, Brookings, So. Dak. 1933 | 17–4–21 | |
| Sweet Bough | W. & T. Smith Co., Geneva, N. Y. 1910 | 17–4–11 | Pollen germination good (8) |
| Sweet Delicious (New York No. 2128) | Deacon Jones × Delicious, introduced 1922 | 17–4–13 | |
| Sweet McIntosh (New York No. 505) | Lawver × McIntosh, introduced 1922 | 17–4–15 | |
| Sweet Russet | Experiment Station, Brookings, So. Dak. 1920 | 21–11–19 | |
| Sweet Winesap | W. & T. Smith Co., Geneva, N. Y. 1897 | 17–10–25 | |
| Switzerland | Sonderreger Nurseries and Seed House, Beatrice, Neb. 1921 | 21–20–13 | |
| Tioga (New York No. 5559–4) | Sutton × Northern Spy, introduced 1915 | 17–4–17 | |
| Tolman Sweet | Ellwanger & Barry, Rochester, N. Y. 1883 | 17–4–19 | Pollen germination good (8) |
| Toshkee | Central Exp. Farm, Ottawa, Canada 1937 | 21–19–31 | McIntosh × Milwaukee |
| University | West Concord Nursery, West Concord, Minn. 1912 | 17–4–23 | |
| Van Eseltine (New York No. 11903) | Malus Arnoldiana × M. spectabilis, introduced 1937 | 1–8–24 | An ornamental crab |
| Wainwright | U.S.D.A., Washington, D. C., S.P.I. 31653, 1918 | 21–6–11 | |
| Wedge (Minn. No. 207) | State Fruit Breeding Farm, Excelsior, Minn. 1927 | 17–6–4 | |
| Westchester (New York No. 94) | Ben Davis × Green Newtown, introduced 1914 | 17–4–34 | |
| White Pippin | Ellwanger & Barry, Rochester, N. Y. 1883 | 17–4–36 | |
| Whitney (crab) | Stark Bros., Louisiana, Mo. 1889 | 17–1–43 | |
| Williams | W. A. Henry & Son, Wallingford, Conn. 1921 | 17–4–38 | |
| Wilson Red June | Stark Bros., Louisiana, Mo. 1909 | 17–4–40 | |
| Young America (crab) | W. & T. Smith Co., Geneva, N. Y. 1907 | 17–1–46 | |
| Zeleba | Experiment Station, Brookings, So. Dak. 1924 | 21–5–5 | |
| | *Triploids* | | |
| Frantz | Sonderreger Nurseries & Seed House, Beatrice, Neb. 1921 | 21–20–17 | Imported from Germany to Minn., introduced about 1902; supposedly hardy |
| King Acre Pippin | Geo. Bunyard & Co., Maidstone, Eng. 1928 | 17–6–30 | |
| Monmouth Beauty | Bountiful Ridge Nurseries, Princess Anne, Md. 1927 | 17–5–27 | |
| New York No. 1256 | Boiken × Wealthy, Cross of 1910 | 21–19–31 | A seedling saved for testing but never named |
| Rheinischer Winter Rambour | Geisenheim, Germany 1931 | 17–10–13 | |
| Staymared | Stark Bros., Louisiana, Mo. 1930 | 17–5–44 | Red sport of Stayman Winesap, a triploid (3) |
| | *Diploid-Tetraploid Chimeras (All Large-Fruited Sports)* | | |
| Grimes Sport | J. A. McClintock, Purdue University, 1948 | Nursery | Reported as "unprofitable" (10), Type 2* |
| "Large" McIntosh | F. W. Cornwall, Pultneyville, N. Y. 1948 | Nursery | Type 3 |
| Ontario Sport | T. C. Maxwell, Geneva, N. Y. 1910 | 17–9–42 | (2, 6), Type 1 |
| "Giant" Wealthy | H. S. Loop, North East, Pa. 1947 | 17–15–4 | (2, 6), Type 1 |
| "Large" Wealthy | R. C Coombs, Henniker, N. H. 1942 | 16–2–11 | Type 2 |
| "Large" Yellow Transparent | D. B. Perrine, Centralia, Ill. 1948 | Nursery | Types 1 and 2 |

*See text for descriptions of the types of chimeras.

Type 2 (two layers diploid) has diploid epidermal and subepidermal layers of cells in the stem apices. The deeper cell layers are all tetraploid. Since sporogenous tissues are derived from the second layer in the apex, the forms representing this type breed like diploids.

Type 3 (three layers diploid) has three layers of diploid cells covering the tetraploid interior in the shoot apex. Sports of this type also behave like diploids when used in breeding.

*Grimes Sport (McClintock)*:—This sport is the large-fruited "unprofitable" strain of the Grimes apple reported by Dr. J. A. McClintock (10) who very kindly sent us material for study. The sport is a chimera of type 2.

*"Large" McIntosh (Cornwall)*:—This sport is of type 3 with a large amount of diploid tissue. The grower who found this form in his McIntosh orchard reports that the fruits are definitely larger than normal McIntosh and that the tree is very productive. Dermen and Darrow (4) have reported another "large" McIntosh sport but of type 1.

*Ontario Sport*:—A tree of the variety Ontario growing in the Station orchard has been found to be a chimera of type 1 and is assumed to be a sport of the true Ontario. As reported previously (6) other material of Ontario obtained from the Horticultural Experiment Station, Vineland Station, Ontario, Canada, from Nova Scotia, and from a local grower was all found to be wholly diploid in agreement with previous findings of Kobel (9) and Nebel (11).

*"Giant" Wealthy (Loop)*:—This large-fruited sport of Wealthy has been found to be of type 1 as was the "Large" Wealthy (Stevenson) reported previously (7). From the available information it is extremely unlikely that these two came from the same original source. The identical sport has apparently occurred at two different times in this instance.

*"Large" Wealthy (Coombs)*:—This large-fruited sport was found to be of type 2, thus differing in makeup and breeding behavior from the other two Wealthy sports.

*"Large" Yellow Transparent (Perrine)*:—Mr. D. B. Perrine of Centralia, Illinois is growing this apple on a small commercial scale to test for future planting and kindly sent us twigs to force for cytological study. It is not definitely known whether the material was collected from one or from more trees. Examination of the buds revealed that some of them were of type 1 and others of type 2. Eleven of the 16 buds were of the first type and the other five were of the second type. This is the first mixture we have detected and a careful check should show whether or not there are two distinct sports in this material.

## Literature Cited

1. Beach, S. A. The apples of New York. 1: 224–225. 1905.
2. Blaser, H. Weston, and Einset, John. Leaf development in six periclinal chromosomal chimeras of apple varieties. *Amer. Jour. Bot.* 35: 473–482. 1948.

3. COOPER, J. R., and WIGGINS, C. B. Cytological studies with apples. *Ark. Exp. Sta. Bul.* 312: 40–41. 1934.
4. DERMEN, HAIG, and DARROW, GEORGE M. A tetraploid sport of McIntosh apples. *Jour. Hered.* 39: 17. 1948.
5. EINSET, JOHN. The occurrence of spontaneous triploids and tetraploids in apples. *Proc. Amer. Soc. Hort. Sci.* 51: 61–63. 1948.
6. ——— BLASER, H. WESTON, and IMHOFE, BARBARA. Chimeral sports of apples. *Jour. Hered.* 38: 371–376. 1947.
7. ——— and IMHOFE, BARBARA. Chromosome numbers of apple varieties and sports. *Proc. Amer. Soc. Hort. Sci.* 50: 45–50. 1947.
8. ELSSMANN, E. Die Befruchtungsverhältnisse bei unseren Obstsorten. *Der Zuchter* 7: 84–95. 1935.
9. KOBEL, F. Zytologische Untersuchungen an Prunoiden und Pomoideen. *Arch. Jul. Klauss. Stift.* 3. 1927.
10. MCCLINTOCK, J. A. An unprofitable strain of the Grimes apple. *Proc. Amer. Soc. Hort. Sci.* 51: 64–66. 1948.
11. NEBEL, B. R. Zur Cytologie von Malus II. *Der. Zuchter* 1: 215–217. 1929.
12. ——— Characteristics of diploid and triploid apple varieties I. Measurement of stomata. *Proc. Amer. Soc. Hort. Sci.* 32: 254–255. 1934.
13. RANDOLPH, L. F. A new fixing fluid and a revised schedule for the paraffin method in plant cytology. *Stain Tech.* 10: 95–96. 1935.

# Growth Characteristics of Certain Cider Apple Varieties and Crab Apples

By F. C. Bradford, *U. S. Department of Agriculture, Glenn Dale, Md.*

Early and abundant cropping will be particularly important if apples are to be grown solely for use as adjuvants in juice manufacture. Advantage was taken, therefore, of the opportunity afforded by the presence in the nursery of trees of cider varieties and crab-apples, to obtain measurements of the growth they made in two years from the bud. They were budded in the summer of 1944 on commercial seedlings, about to complete their second year, in plots of five trees each randomized in 10 blocks. In general, differences of less than 10 per cent are not reliably significant.

There were five crabapples in the test. Wabiskaw and Babine (*Malus baccata* x *Malus silvestris* var. Niedzwetzkyana) are forms selected at Ottawa as ornamentals (3), but have a high "tannin" content, and were supplied by M. B. Davis, Dominion Horticulturist. Rosthern No. 18 and No. 22 are products of the Canadian Station of the same name, where –35 degrees F can be expected every winter and –50 degrees F about once every 10 years, and are as astringent as most of the cider varieties. The fifth crabapple is supposedly, but dubiously, Transcendent.

The cider apples come from France and England, and are mostly bittersweet. Foxwhelp is a bitter-sharp, and Kingston Black is a vintage apple, meaning that its juice, with nothing added, makes a very good fermented cider, but it falls in the bitter-sharp class. Reine des Pommes corresponds with descriptions in every respect but flavor, being sweet instead of bittersweet. Bramtot, Medaille d'Or, Amère de Berthecourt and Amer Gautier have fruited, verifying their descriptions; for the verity of the other varieties we have to rely on descriptions of vegetative characters only.

At the beginning of the 1945 growing season, certain of these clones received a check in growth from frosts on April 6 and 7, which caused a variable amount of injury stated approximately in Table I. The average number of crabapples injured was 59 per cent; of cider apples, 17 per cent. Rarely was more than 5 cm of growth affected, usually less, but there was a noticeable check in the growth of some varieties, and none at all in others.

Fire blight in 1945 affected Rosthern No. 18, one tree; Babine four trees. In 1946, in addition to these, it affected Transcendent one tree; Kingston Black one tree; Rosthern No. 18, four trees; Babine, five trees and Wabiskaw three trees.

If the length growth for 1946 is compared with the figures for 1945, some interesting bouleversements appear. Bramtot is the only one of the first four varieties in 1945 to place among the first four in 1946. Strawberry Norman, second in 1945, was eleventh in 1946. Medaille d'Or, which was tied for fifth in 1945 was fifteenth in 1946, and made only 6 cm more growth in 1946 than it made in 1945.

Every crabapple in the test improved its position with reference to the other varieties in 1946. They made almost all their growth in the early part of the season; the cider apples as a group start later and grow somewhat later. In their second and subsequent seasons, the growth in the crabapple not being confined to one growing point, exuberance of growth has more opportunity to manifest itself than it has in the first year. This consideration seems to weigh more in determining growth for the season than length of the individual shoot or even than number of shoots. This is not intended to imply that either of these is without influence; we have only to compare the first four and the last four to see what happens when all three influences combine.

The trunk diameters are not quite in the order of the length growths, but they show the same invariable tendency of the crabapples to improve their relative position in 1946 as compared with 1945. Certain of the cider varieties, such as Knotted Kernel, also improved their relative standing, while the falling off of certain other varieties, such as Strawberry Norman, Kingston Black, and Medaille d'Or, is so considerable that it is not accounted for merely by displacement by other varieties. As appears in Table III, the inclination to late growth in the cider varieties is manifest in diameter increase. The branch diameter, as revealed by figures in Table I, which gives figures on branches measured at 20 cm from the trunk, has little or no relation to trunk diameter.

A few trees of each variety were left in place, undisturbed, for a third year. Blossoming occurred on several trees of Amer Gautier

TABLE I—FROST INJURY, SHOOT AND DIAMETER DEVELOPMENT OF CIDER VARIETIES AND CERTAIN CRABAPPLES

| Variety | Trees (No) | Trees Frost Injured (Per Cent) | Shoots | | | | Trunk Diameter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | Cm Per Shoot | Diameter | | 1945 | | 1946 | | Increase | |
| | | | | | Ave | Rank | Mm | Rank | Mm | Rank | Mm | Rank |
| Bramtot*..... | 50 | 0 | 10 | 40 | 4.1 | 3 | 11.5 | 3 | 18.3 | 1 | 159 | 4 |
| Knotted Kernel | 48 | 54 | 10 | 34 | 4.1 | 5 | 10.6 | 5 | 18.1 | 2 | 169 | 2 |
| Wabiskaw .... | 46 | 80 | 12 | 37 | 3.3 | 13 | 9.2 | 14 | 17.9 | 3 | 184 | 1 |
| Rosthern No. 18 | 44 | 17 | 10 | 40 | 3.6 | 9 | 10 1 | 6 | 17.8 | 4 | 169 | 2 |
| Bonté Normand | 50 | 23 | 10 | 34 | 3.8 | 8 | 11.6 | 2 | 17.3 | 5 | 129 | 9 |
| Reine des Pommes........ | 48 | 0 | 8 | 49 | 4.2 | 2 | 10.8 | 4 | 17.0 | 6 | 135 | 7 |
| Babine. ...... | 28 | 62 | 9 | 40 | 3.1 | 15 | 9.6 | 11 | 16.6 | 7 | 144 | 5 |
| Transcendent.. | 45 | 54 | 11 | 42 | 3.4 | 12 | 9.3 | 13 | 16.4 | 8 | 143 | 6 |
| Strawberry Norman..... | 49 | 4 | 6 | 38 | 4.1 | 4 | 11.7 | 1 | 16.4 | 9 | 104 | 11 |
| Amère de Berthecourt..... | 48 | 52 | 10 | 37 | 4.0 | 6 | 9.7 | 10 | 16 1 | 10 | 130 | 8 |
| Foxwhelp..... | 51 | 6 | 8 | 27 | 3.2 | 14 | 9.8 | 9 | 14.7 | 11 | 95 | 12 |
| Rosthern No. 22.......... | 48 | 82 | 10 | 24 | 2.9 | 16 | 8.2 | 15 | 14.6 | 12 | 114 | 10 |
| Kingston Black | 49 | 2 | 9 | 27 | 3.5 | 11 | 10.0 | 7 | 14.0 | 13 | 76 | 13 |
| Bedan des Partes ..... | 48 | 0 | 4 | 28 | 3.9 | 7 | 9.4 | 12 | 12.9 | 14 | 62 | 14 |
| Medaille d'Or.. | 47 | 0 | 2 | 43 | 4.5 | 1 | 9.8 | 8 | 12.7 | 15 | 52 | 15 |
| Amer Gautier.. | 42 | 0 | 4 | 29 | 3.6 | 10 | 7.6 | 16 | 10.8 | 16 | 47 | 16 |

*Since some varieties were obtained from more than one source, the P. I. numbers of those in this test are stated, in the order in which they appear in this table: 122600; 131600; 148503; 144027; 123734; 131201; 148490; B35645; 131602; 127311; 131598; 144029; 131599; 123733; 127315 and 136243.

TABLE II—LENGTH GROWTH AT VARIOUS PERIODS IN 1945 AND IN 1946

| | 1945 | | | | | | | | | 1946 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 7 | Jun 4 | Jul 2 | | Jul 30 | Aug 27 | Sep 24 | Oct 22 | | | |
| | Cm | Cm | Cm | Rank | Cm | Cm | Cm | Cm | Rank | Cm | Rank |
| Transcendent | 11 | 45 | 65 | 6 | 84 | 101 | 103 | 103 | 5 | 485 | 1 |
| Wabiskaw | 13 | 47 | 57 | 11 | 64 | 75 | 77 | 77 | 12 | 431 | 2 |
| Rosthern No. 18 | 23 | 60 | 81 | 1 | 92 | 94 | 94 | 94 | 9 | 417 | 3 |
| Bramtot | 8 | 33 | 57 | 11 | 76 | 94 | 103 | 104 | 4 | 393 | 4 |
| Amère de Berthecourt | 4 | 34 | 55 | 16 | 72 | 86 | 92 | 92 | 10 | 385 | 5 |
| Reine des Pommes | 11 | 39 | 68 | 4 | 94 | 114 | 124 | 126 | 1 | 383 | 6 |
| Babine | 11 | 45 | 63 | 15 | 63 | 74 | 76 | 76 | 13 | 370 | 7 |
| Knotted Kernel | 8 | 38 | 64 | 6 | 86 | 103 | 108 | 109 | 3 | 340 | 8 |
| Bonté Normand | 9 | 41 | 69 | 3 | 90 | 100 | 103 | 103 | 5 | 327 | 9 |
| Kingston Black* | 9 | 36 | 56 | 14 | 73 | 87 | 99 | 101 | 8 | 259 | 10 |
| Strawberry Norman | 8 | 39 | 75 | 2 | 103 | 113 | 116 | 116 | 2 | 247 | 11 |
| Rosthern No. 22 | 6 | 34 | 58 | 9 | 65 | 65 | 65 | 65 | 16 | 242 | 12 |
| Foxwhelp* | 13 | 39 | 66 | 5 | 82 | 88 | 89 | 89 | 11 | 229 | 13 |
| Bedan des Partes | 11 | 40 | 57 | 11 | 62 | 69 | 73 | 73 | 14 | 115 | 14 |
| Medaille d'Or | 6 | 37 | 61 | 8 | 79 | 81 | 101 | 103 | 5 | 109 | 15 |
| Amer Gautier | 6 | 38 | 58 | 9 | 65 | 66 | 66 | 66 | 15 | 106 | 16 |

*In a subsequent comparison Kingston Black and Foxwhelp made practically identical whip growths.

TABLE III—TRUNK DIAMETER (MM) AT VARIOUS PERIODS IN 1945 AND 1946, WITH RANKINGS

| | 1945 | | | | | | 1946 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jun 24 | Jul 22 | Aug 19 | Sep 16 | Oct 12 | Rank | Jun 24 | Jul 22 | Aug 19 | Sep 16 | Oct 12 | Rank |
| Bramtot | 7.6 | 9.4 | 10.5 | 11.3 | 11.5 | 3 | 14.5 | 16.0 | 17.5 | 18.1 | 18.3 | 1 |
| Knotted Kernel | 7.3 | 8.9 | 9.6 | 10.5 | 10.6 | 5 | 14.5 | 16.2 | 17.3 | 18.1 | 18.1 | 2 |
| Rosthern No. 18 | 8.1 | 9.4 | 10.0 | 10.2 | 10.1 | 6 | 14.6 | 16.7 | 17.6 | 17.9 | 17.9 | 3 |
| Wabiskaw | 7.4 | 8.2 | 9.0 | 9.4 | 9.3 | 14 | 14.1 | 16.3 | 17.4 | 17.9 | 17.9 | 4 |
| Bonté Normand | 8.1 | 9.6 | 9.1 | 11.4 | 11.6 | 2 | 14.4 | 16.0 | 16.8 | 17.2 | 17.3 | 5 |
| Reine des Pommes | 8.2 | 9.1 | 9.9 | 10.7 | 10.8 | 4 | 14.0 | 15.4 | 16.4 | 17.0 | 17.2 | 6 |
| Babine | 7.6 | 8.6 | 9.3 | 9.7 | 9.6 | 11 | 13.8 | 15.4 | 16.4 | 16.6 | 16.6 | 7 |
| Strawberry Norman | 8.3 | 10.0 | 11.3 | 11.7 | 11.7 | 1 | 13.6 | 15.0 | 15.6 | 16.4 | 16.4 | 8 |
| Transcendent | 7.4 | 8.6 | 9.1 | 9.4 | 9.3 | 13 | 13.5 | 15.3 | 16.0 | 16.4 | 16.4 | 9 |
| Amère de Berthecourt | 7.2 | 8.2 | 8.9 | 9.6 | 9.7 | 10 | 13.0 | 14.2 | 15.4 | 16.0 | 16.1 | 10 |
| Foxwhelp | 7.7 | 8.8 | 9.5 | 9.7 | 9.8 | 9 | 12.1 | 13.5 | 14.3 | 14.4 | 14.7 | 11 |
| Rosthern No. 22 | 6.5 | 7.7 | 8.2 | 8.5 | 8.2 | 15 | 12.8 | 14.3 | 14.5 | 14.6 | 14.6 | 12 |
| Kingston Black | 7.5 | 8.6 | 9.3 | 9.9 | 10.0 | 7 | 11.7 | 12.7 | 13.5 | 13.8 | 14.0 | 13 |
| Bedan des Partes | 7.0 | 7.9 | 8.7 | 9.4 | 9.4 | 12 | 10.3 | 11.2 | 12.2 | 12.8 | 12.9 | 14 |
| Medaille d'Or | 7.4 | 8.3 | 9.1 | 9.7 | 9.8 | 8 | 10.5 | 11.3 | 12.0 | 12.5 | 12.7 | 15 |
| Amer Gautier | 6.5 | 7.2 | 7.6 | 7.6 | 7.6 | 16 | 9.5 | 10.5 | 10.7 | 10.8 | 10.8 | 16 |

and of Rosthern No. 22; Amère de Berthecourt, Medaille d'Or, Bonté Normand and Bramtot have borne early on other trees. Medaille d'Or has been the most productive of 20 varieties in the first 5 years of bearing in one test in England. (1) Amer Gautier is very late blossoming, almost as late as Medaille d'Or, and has attracted some attention (2) by its resistance, above most cider varieties, to winter cold.

## LITERATURE CITED

1. BALL, E. Long Ashton Research Station trial plot of bush cider varities. *Herefordshire Agr. Jour.* 11 : 1 : 61–63. 1948.
2. BALTET, CH. Traité de la culture fruitière. *Le Cidre et le Poiré.* 20 : 9 : 266–268. 1909.
3. PRESTON, ISABELLA. Rosybloom crabapples at Central Experimental Farms. *Canadian Hort. & Home.* 64 : 5 : 93, 102. 1941.

# Characteristics of Progeny from Certain Apple Crosses

By G. William Schneider, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

There has been a need for better apple varieties in New Jersey for a number of years. To meet this need, an apple breeding program was initiated by the late Professor M. A. Blake in 1925. This paper presents a summary of the data describing characteristics of the progeny obtained from this project. The statistical limitations of the data are appreciated. However, it is felt that most of these progenies are large enough to give a reliable indication of what one might expect from a given combination of parents. The trees were originally set 4 feet apart in rows 15 feet apart.

In almost all cases, the fruits were described and maturity date records were made by Professor Blake. The records were made during the period 1940 to 1947 with the two exceptions of Williams x Starr and Wealthy x Starr. Data on the Starr crosses were taken from 1932 to 1937. Records were not always complete for each character on each seedling. This accounts for the variation in number of seedlings of a given cross reported for each character. Many of the seedling records were for one year only, since any seedling that did not have some particularly desirable characteristic was removed from the orchard the first winter after fruiting.

## Presentation of Data

*Fruit Size:*—The data for each cross reported on are given in Table I. The fruits were placed in four classes according to size, namely, class I, small; class II, medium small and medium; class III, medium large; class IV, large and very large.

Of the varieties used Yellow Newtown was the most outstanding parent as far as transmitting fruit size is concerned. A high per cent of the progeny produced fruit of class IV size (large and very large). Edgewood also produced a high per cent of progeny with large or larger fruit. A cross of Gravenstein x Orleans produced a progeny in which 74 per cent of the seedlings that fruited bore large or very large fruit. Slightly over half of the original number of trees from this cross have fruited. This is somewhat surprising in view of the triploid chromosome number of the pistillate parent. Triploid parents have been reported (1) as producing weak seedlings.

At least 50 per cent of the seedlings where Petrel was one of the parents have produced class IV size fruit except where it was crossed with Jonathan. The crosses, Williams x Starr and Wealthy x Starr, also produced seedlings over half of which produced class IV size fruit. However, the Petrel and Starr progeny were not as outstanding in fruit size as were those of Yellow Newtown and Edgewood. The crosses Melba x N. J. 130 (Wealthy x Starr), Melba x Kildare, Anoka x Kildare, and Arkansas Black x Macoun were the poorest combinations in respect to fruit size of seedlings. Less than 20 per cent of these progenies produced class IV size fruit.

TABLE I—Progeny of Apple Crosses Classified According to Fruit Size

| Cross | No. of Trees | Per Cent of Progeny in Classes* | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Petrel × Jonathan | 15 | 7 | 33 | 40 | 20 |
| Petrel × Cortland | 29 | 7 | 17 | 21 | 55 |
| Petrel × Early McIntosh | 17 | 18 | 12 | 12 | 58 |
| Petrel × N. J. 130 (Wealthy × Starr) | 16 | 0 | 19 | 13 | 68 |
| Melba × Twenty Ounce | 32 | 13 | 6 | 28 | 53 |
| Melba × N. J. 130 (Wealthy × Starr) | 25 | 24 | 32 | 36 | 8 |
| Melba × N. J. 53 (Williams × Starr) | 33 | 6 | 30 | 18 | 46 |
| Melba × Kildare | 56 | 30 | 25 | 30 | 15 |
| Anoka × Kildare | 33 | 27 | 40 | 15 | 18 |
| Red Gravenstein × Orleans | 27 | 4 | 15 | 7 | 74 |
| Williams × Starr | 30 | 7 | 17 | 20 | 56 |
| Wealthy × Starr | 84 | 4 | 19 | 23 | 54 |
| Red Rome × Melba | 22 | 5 | 27 | 32 | 36 |
| Red Rome × Petrel | 22 | 5 | 11 | 32 | 50 |
| Red Rome × Twenty Ounce | 60 | 3 | 10 | 20 | 67 |
| Red Rome × Jonathan | 34 | 6 | 18 | 29 | 47 |
| Golden Delicious × Edgewood | 42 | 5 | 5 | 33 | 57 |
| Golden Delicious × Red Rome | 67 | 9 | 27 | 21 | 43 |
| Golden Delicious × Cortland | 29 | 10 | 14 | 28 | 48 |
| Golden Delicious × White Winter Pearmain | 68 | 13 | 16 | 24 | 47 |
| Yellow Newtown × Red Rome | 31 | 3 | 3 | 13 | 81 |
| Yellow Newtown × Golden Delicious | 21 | 0 | 19 | 5 | 76 |
| Yellow Newtown × Edgewood | 13 | 0 | 8 | 8 | 84 |
| Gallia Beauty × White Winter Pearmain | 130 | 20 | 38 | 20 | 22 |
| Gallia Beauty × Macoun | 65 | 8 | 24 | 34 | 34 |
| Arkansas Black × Macoun | 22 | 27 | 32 | 23 | 18 |

*Class I—small.
Class II—medium small and medium.
Class III—medium large to large.
Class IV—large to very large.

Fig. 1 shows graphically the percentage of progeny from the 10 combinations that developed the highest per cent of seedlings producing class III and IV size fruit. It may be noted that the progenies of the varieties Yellow Newtown and Edgewood are outstanding in

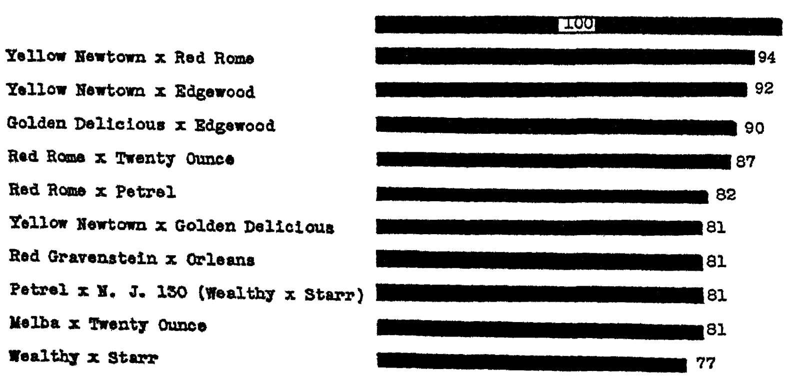


Fig. 1. Percentage of seedlings from selected apple crosses producing fruits medium large and larger.

fruit size of seedlings. The varieties Twenty Ounce and Red Rome also carry factors for desirable fruit size. At least 81 per cent of the progenies from crosses of these produced medium large or larger fruit, except when Red Rome was crossed with Melba, Jonathan, and Golden Delicious.

*Over Color:*—Table II gives distribution of progeny according to the amount of red surface color. Macoun progeny have been outstanding for color development in the crosses Arkansas Black x Macoun and Gallia Beauty x Macoun. It may be noted that over 65 per cent of the seedlings from each cross produced fruit with at least 75 per cent of the surface covered with red. Although it is not shown in the data, approximately half of the Macoun seedlings developed red coloring over at least 90 per cent of the fruit surface. Most of these seedlings that developed high color were also outstanding for good finish and attractive coloration. Work of Hartman and Howlett (2) showed a considerable proportion of the seedlings from selfed Gallia Beauty produced fruit with no over color. It should also be pointed out that Gallia Beauty crossed with White Winter Pearmain produced a progeny, half of which developed red coloration over 75 per cent of the surface. Red Rome was not as

TABLE II—PROGENY OF APPLE CROSSES CLASSIFIED ACCORDING TO AMOUNT OF SURFACE COLOR

| Cross | No. of Trees | Per Cent of Progeny in Classes* | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Petrel × Jonathan | 15 | 20 | 40 | 27 | 13 |
| Petrel × Cortland | 23 | 22 | 17 | 39 | 22 |
| Petrel × Early McIntosh | 16 | 44 | 25 | 0 | 31 |
| Petrel × N. J. 130 (Wealthy × Starr) | 16 | 44 | 6 | 38 | 12 |
| Melba × Twenty Ounce | 30 | 20 | 23 | 30 | 27 |
| Melba × N. J. 130 (Wealthy × Starr) | 23 | 17 | 13 | 39 | 31 |
| Melba × N. J. 53 (Williams × Starr) | 27 | 0 | 37 | 37 | 26 |
| Melba × Kildare | 50 | 56 | 20 | 16 | 8 |
| Anoka × Kildare | 29 | 48 | 24 | 18 | 10 |
| Red Gravenstein × Orleans | 27 | 41 | 0 | 15 | 44 |
| Williams × Starr | 19 | 68 | 16 | 5 | 11 |
| Wealthy × Starr | 26 | 50 | 0 | 24 | 26 |
| Red Rome × Melba | 22 | 14 | 23 | 9 | 54 |
| Red Rome × Petrel | 21 | 10 | 19 | 19 | 52 |
| Red Rome × Twenty Ounce | 59 | 20 | 10 | 19 | 51 |
| Red Rome × Jonathan | 34 | 12 | 6 | 26 | 56 |
| Golden Delicious × Edgewood | 40 | 10 | 15 | 45 | 30 |
| Golden Delicious × Red Rome | 66 | 47 | 5 | 6 | 42 |
| Golden Delicious × Cortland | 30 | 53 | 3 | 10 | 34 |
| Golden Delicious × White Winter Pearmain | 67 | 98 | 0 | 1 | 1 |
| Yellow Newtown × Red Rome | 27 | 38 | 11 | 22 | 30 |
| Yellow Newtown × Golden Delicious | 21 | 81 | 5 | 9 | 5 |
| Yellow Newtown × Edgewood | 13 | 23 | 31 | 31 | 15 |
| Gallia Beauty × White Winter Pearmain | 115 | 40 | 2 | 7 | 51 |
| Gallia Beauty × Macoun | 64 | 0 | 9 | 25 | 66 |
| Arkansas Black × Macoun | 22 | 0 | 14 | 14 | 72 |

*Class I—red color on 0 to 24 per cent of surface.
Class II—red color on 25 to 49 per cent of surface.
Class III—red color on 50 to 74 per cent of surface.
Class IV—red color on 75 to 100 per cent of surface.

outstanding as Macoun in transmitting red color. However, when Red Rome was crossed with the varieties Melba, Petrel, Twenty Ounce, and Jonathan over half the seedlings produced fruit with three-quarters of the surface covered with red. The crosses involving only red varieties that gave the lowest percentage of seedlings with three-quarters of the surface red included Petrel crossed with Jonathan and N. J. 130 (Wealthy x Starr), and Anoka x Kildare. The low per cent of seedlings from the Petrel x Jonathan cross that produced well colored fruit is not entirely in accord with the work of Vincent and Longley (4) who found that Jonathan had a practically dominant factor for red color over lack of red color. It should be pointed out that approximately 20 per cent of the seedlings from the cross Yellow Newtown x Golden Delicious produced fruit with red over color on at least 25 per cent of the surface. This is not in agreement with the common conception that yellow is recessive to red. However, Wellington (5) reported red fruited seedlings in the progeny of Yellow Newtown x Fall Pippin.

Fig. 2 shows in descending order 10 of the combinations developing red color on more than half of the fruit surface. Crosses most outstanding in this grouping were Gallia Beauty x Macoun, Arkansas Black x Macoun, and Red Rome x Jonathan. Over 80 per cent of the progenies of these crosses produced fruit with red color on at least 50 per cent of the surface. Seventy-five per cent of the seedlings from the cross Golden Delicious x Edgewood produced fruit with color on at least half the surface. This is in agreement with the work of Crane and Lawrence (1) indicating inheritance and distribution of anthocyanin is controlled by a number of genes.

*Fruit Quality:*—Table III gives the distribution of progeny according to fruit quality. Four classes were established as follows: class I, poor quality; class II, medium quality; class III, fairly good to good quality; and class IV, very good dessert quality. The best combination for production of class IV dessert quality was Golden Delicious x White Winter Parmain. Twenty-four per cent of the seedlings of this cross produced fruit of very good quality. At least

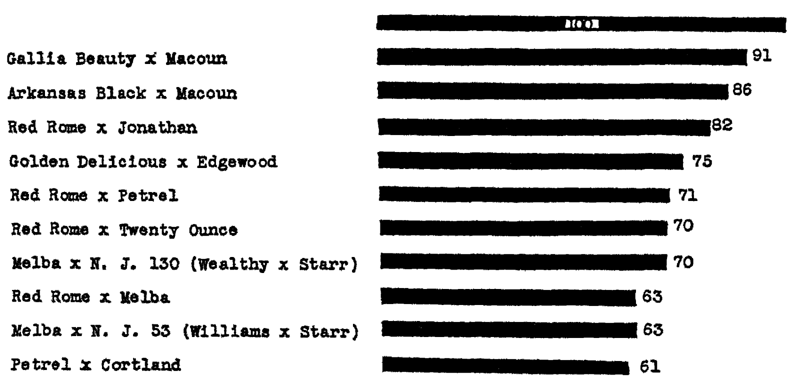


FIG. 2. Percentage of seedlings from selected apple crosses producing fruits with at least 50 per cent red color.

TABLE III—PROGENY OF APPLE CROSSES CLASSIFIED ACCORDING TO QUALITY

| Cross | No. of Trees | Per Cent of Progeny in Classes* | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Petrel × Jonathan | 14 | 0 | 64 | 36 | 0 |
| Petrel × Cortland | 23 | 17 | 48 | 30 | 5 |
| Petrel × Early McIntosh | 15 | 20 | 33 | 47 | 0 |
| Petrel × N. J. 130 (Wealthy × Starr) | 16 | 6 | 56 | 38 | 0 |
| Melba × Twenty Ounce | 31 | 10 | 65 | 25 | 0 |
| Melba × N. J. 130 (Wealthy × Starr) | 23 | 17 | 44 | 39 | 0 |
| Melba × N. J. 53 (Williams × Starr) | 30 | 37 | 40 | 23 | 0 |
| Melba × Kildare | 53 | 26 | 55 | 19 | 0 |
| Anoka × Kildare | 28 | 68 | 25 | 7 | 0 |
| Red Gravenstein × Orleans | 24 | 13 | 46 | 41 | 0 |
| Williams × Starr | 22 | 64 | 32 | 4 | 0 |
| Wealthy × Starr | 61 | 23 | 43 | 31 | 3 |
| Red Rome × Melba | 22 | 14 | 50 | 23 | 13 |
| Red Rome × Petrel | 21 | 5 | 48 | 43 | 4 |
| Red Rome × Twenty Ounce | 55 | 13 | 49 | 38 | 0 |
| Red Rome × Jonathan | 34 | 0 | 29 | 59 | 12 |
| Golden Delicious × Edgewood | 39 | 0 | 23 | 74 | 3 |
| Golden Delicious × Red Rome | 58 | 0 | 21 | 69 | 10 |
| Golden Delicious × Cortland | 28 | 0 | 32 | 64 | 4 |
| Golden Delicious × White Winter Pearmain | 54 | 0 | 7 | 69 | 24 |
| Yellow Newtown × Red Rome | 25 | 0 | 24 | 76 | 0 |
| Yellow Newtown × Golden Delicious | 21 | 10 | 24 | 56 | 10 |
| Yellow Newtown × Edgewood | 12 | 0 | 42 | 58 | 0 |
| Gallia Beauty × White Winter Pearmain | 112 | 2 | 75 | 23 | 0 |
| Gallia Beauty × Macoun | 58 | 2 | 74 | 24 | 0 |
| Arkansas Black × Macoun | 18 | 17 | 44 | 39 | 0 |

*Class I—poor quality.
Class II—medium quality.
Class III—fairly good to good quality.
Class IV—very good quality.

10 per cent of the seedlings from the crosses Red Rome x Melba, Red Rome x Jonathan, Golden Delicious x Red Rome, and Yellow Newtown x Golden Delicious produced very good quality fruit. Fig. 3 shows graphically in descending order the combinations which gave the greatest per cent of fruits of class III and IV quality (fairly good to very good). In this combination Golden Delicious x White Winter Pearmain was again superior. Among the combinations discussed here, Golden Delicious was definitely superior in transmitting quality for when crossed with five different varieties, it produced a high percentage of seedlings ranking relatively high in quality. Yellow Newtown also transmitted superior fruit quality for all crosses involving this variety rank among those producing the highest per cent of seedlings with good or better quality. The same may also be said of the two crosses of Edgewood. Many of the seedlings of Edgewood were also high in acidity. It should be noted that many of the seedlings from four of the six crosses of Red Rome were fairly good or better in quality. The crosses of Williams x Starr, Anoka x Kildare, Gallia Beauty x White Winter Pearmain, Gallia Beauty x Macoun, and crosses of Melba x Twenty Ounce, Kildare and N. J. 53 (Williams

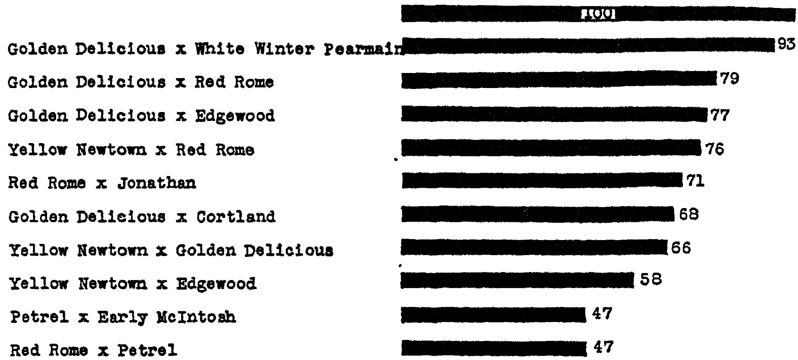


FIG. 3. Percentage of seedlings from selected apple crosses producing fruits fairly good to better in dessert quality.

x Starr) were all definitely inferior in transmitting desirable quality to the progenies.

*Time of Ripening:*—Table IV gives the distribution of progeny according to the date of maturity of the fruit. For most of the crosses the ripening date of more than half of each progeny has been between the ripening dates of the parents of that progeny. In these cases a few of the seedlings matured before the parents and a few matured later than the parents. Certain crosses did not follow this pattern. At least *half* the progeny from the crosses Melba x New Jersey 130 (Wealthy x Starr), Melba x N. J. 53 (Williams x Starr), Anoka x Kildare, and Gallia Beauty x White Winter Pearmain matured their fruit before the earlier maturing parent. A seedling from the Red Rome x Jonathan cross matured August 13 in 1948. The fruits were bright red over most of the surface, showed good finish in a critical season, were exceptionally firm, and hung to the tree well for the season of maturity. Over 90 per cent of the progeny of the cross Red Gravenstein x Orleans matured their fruit after Orleans was harvested. The crosses, Petrel x Early McIntosh, Petrel x N. J. 130, Melba x Twenty Ounce, Williams x Starr, Golden Delicious x Edgewood, and Golden Delicious x Cortland, produced over 60 per cent seedlings which matured the fruit later than the latest ripening parent.

Many of the New Jersey fruit growers prefer an apple variety with a smaller tree than McIntosh or Baldwin. Thus, seedlings with other desirable characteristics were left in the orchard even though they were not developing into a large tree. As a result of this practice, there are now growing at New Brunswick a considerable number of seedlings that are smaller than the standard tree. There are all degrees of dwarfness, productiveness, and tree vigor in these seedlings. In 1948 the blooming date of these dwarf seedlings was later than the standard-size trees. The average blooming date of the 11 dwarf trees remaining in the orchard from the cross, Gallia Beauty x White Winter Pearmain, was May 11 while the average

TABLE IV—PROGENY OF APPLE CROSSES CLASSIFIED ACCORDING TO DATE OF MATURITY

| Cross | Maturity Date of Parent | No. of Trees | Per Cent of Progeny Maturing: Jul 11–17 | Jul 18–24 | Jul 25–31 | Aug 1–7 | Aug 8–14 | Aug 15–21 | Aug 22–28 | Aug 29–Sep 4 | Sep 5–11 | Sep 12–18 | Sep 19–25 | Sep 26–Oct 2 | Oct 3–9 | Oct 10–16 | Oct 17–23 | Oct 24–30 | Oct 31–Nov 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Petrel* | Aug 12 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Petrel × Jonathan* | Sep 25 | 15 | — | — | 7 | 7 | 13 | 7 | 7 | 40 | — | — | 7 | 13 | — | — | — | — | — |
| Petrel × Cortland* | Sep 25 | 30 | — | — | 7 | 10 | 24 | — | 13 | 10 | 13 | 7 | 3 | 10 | — | 3 | — | — | — |
| Petrel × Early McIntosh* | Aug 10 | 15 | 7 | 7 | 13 | — | 7 | — | — | 46 | 7 | — | 7 | — | — | 7 | — | — | — |
| Petrel × N. J. 130* | Aug 22 | 18 | — | — | 6 | 6 | 11 | 6 | — | 22 | 16 | 11 | 6 | 16 | — | — | — | — | — |
| Melba* | Aug 10 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Melba × Twenty Ounce* | Aug 20 | 35 | — | — | 9 | 6 | 6 | 11 | 23 | 34 | 6 | — | — | 6 | — | — | — | — | — |
| Melba × N. J. 130* | Aug 5 | 25 | 4 | — | 24 | 28 | 8 | 4 | 8 | 16 | — | 4 | — | — | — | 4 | — | — | — |
| Melba × N. J. 53* | Aug 5 | 35 | 3 | 3 | 34 | 14 | 11 | 11 | 6 | 9 | 9 | — | — | — | — | — | — | — | — |
| Melba × Kildare* | Sep 5 | 62 | — | — | — | 10 | 5 | 22 | 18 | 16 | 13 | 13 | 3 | — | — | — | — | — | — |
| Anoka* × Kildare | Aug 20 | 37 | — | 3 | 3 | 24 | 16 | 19 | 3 | 16 | — | 8 | 3 | — | — | 5 | — | — | — |
| Red Gravenstein* | Aug 20 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Red Gravenstein × Orleans* | Sep 25 | 25 | — | — | — | — | 4 | — | — | — | — | — | — | 24 | 20 | 20 | 24 | 8 | — |
| Williams* | Aug 5 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Williams × Starr* | Aug 10 | 30 | — | — | — | 10 | 17 | 40 | 23 | 7 | 3 | — | — | — | — | — | — | — | — |
| Wealthy* × Starr | Aug 30 | 84 | — | — | — | 2 | 10 | 27 | 27 | 15 | 13 | 2 | 1 | 1 | 1 | — | — | 1 | — |
| Red Rome* | Oct 15 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Red Rome × Melba* | Aug 10 | 23 | — | 4 | — | — | 13 | 9 | 4 | 9 | 4 | 4 | 14 | 4 | 4 | 9 | 18 | — | 4 |
| Red Rome × Petrel* | Aug 12 | 24 | — | — | — | — | — | — | — | 4 | 33 | 17 | 12 | — | 4 | 17 | 12 | — | — |
| Red Rome × Twenty Ounce* | Aug 20 | 60 | — | — | — | 2 | — | — | 2 | 3 | 5 | 2 | 8 | 17 | 8 | 15 | 30 | 13 | 5 |
| Red Rome × Jonathan* | Sep 25 | 34 | — | — | — | — | — | — | 3 | 3 | 6 | — | 6 | 9 | 25 | 15 | 21 | 12 | — |
| Golden Delicious* | Oct 3 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Gold. Delicious × Edgewood* | Sep 25 | 44 | — | — | — | — | — | — | — | 9 | 5 | — | 9 | 2 | 14 | 11 | 32 | 18 | — |
| Gold. Delicious × Red Rome* | Oct 15 | 67 | — | — | — | — | — | 6 | 2 | 3 | — | 4 | 16 | 18 | 21 | 18 | 10 | 2 | — |
| Gold. Delicious × Cortland* | Sep 25 | 29 | — | — | — | — | — | — | — | 3 | — | — | 14 | 20 | 14 | 20 | 29 | — | — |
| Gold. Del. × W.W. Pearmain* | Nov 1 | 74 | — | — | — | — | — | — | 1 | — | — | 3 | 9 | 15 | 17 | 22 | 22 | 9 | 1 |
| Yellow Newtown* | Oct 25 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Yel. Newtown × Red Rome* | Oct 15 | 31 | — | — | — | — | — | — | — | — | 3 | — | 3 | 1 | 6 | 13 | 71 | 3 | — |
| Yel. Newtown × Gold. Del.* | Oct 3 | 21 | — | 5 | — | 9 | 5 | — | — | — | 5 | — | — | — | 9 | 24 | 24 | — | 19 |
| Yel. Newtown × Edgewood* | Sep 25 | 13 | — | — | — | — | — | — | — | — | — | — | — | — | — | 15 | 47 | 23 | 15 |
| Gallia Beauty* | Oct 15 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Gallia Beauty × W.W. Pearmain* | Nov 1 | 152 | — | — | — | — | — | — | — | — | — | — | 2 | 13 | 28 | 24 | 20 | 13 | — |
| Gallia Beauty × Macoun* | Sep 15 | 83 | — | — | — | — | — | — | — | 1 | 4 | 6 | 5 | 28 | 32 | 10 | 13 | 1 | — |
| Arkansas Black* × Macoun | Oct 25 | 26 | — | — | — | — | — | — | — | 4 | 12 | 8 | 4 | 15 | 34 | | 15 | 8 | — |

*Parent for which ripening date is given.

blooming date of the eight standard size trees from the same cross was May 4. This is a rather small number of progeny; but the same observation holds on other crosses that produced semi-standard or smaller trees.

Another point of interest is that a seedling of the cross Petrel x Orleans apparently has a high level of resistance to scab. In 1947 and 1948, trees of this variety retained their leaves and appeared to be free of scab in an orchard where all other varieties and selections were almost completely defoliated by scab. Young trees of this seedling were sent to Dr. Shay at Purdue University who has developed a technique for determining resistance of apple species and varieties to scab. Using this method of artificial inoculation under controlled greenhouse conditions, Shay (3) found it had a high level of resistance but some infection and sporulation did occur.

## Discussion

The most outstanding crosses from the standpoint of large fruit size, quality, and red surface color of the fruit were Gravenstein x Orleans, Red Rome x Twenty Ounce, Red Rome x Jonathan, Yellow Newtown x Red Rome, Red Rome x Petrel, Red Rome x Melba, and Gallia Beauty x Macoun. It is interesting to note that this grouping contains five of the six crosses where Red Rome was one of the parents, since Hartman and Howlett (2) have presented data showing Rome Beauty as failing to transmit these characters to a satisfactory extent. The less desirable crosses in this same grouping were Anoka x Kildare, Melba x Kildare, and Petrel x Jonathan.

A combination of the two best groups (classes III and IV) of the characteristics of fruit color, quality, and size shows that the following crosses were the best combinations among those reported. They were Golden Delicious x Edgewood, Red Rome x Jonathan, Yellow Newtown x Red Rome, Red Rome x Petrel, Yellow Newtown x Edgewood, Red Rome x Twenty Ounce, and Golden Delicious x Red Rome. This again emphasizes the ability of Red Rome to transmit these three characters. The crosses Anoka x Kildare, Melba x Kildare, and Williams x Starr were definitely inferior in transmitting the characters of fruit size, quality, and surface coloration in this grouping.

## Literature Cited

1. Crane, M. B., and Lawrence, W. J. C. The Genetics of Garden Plants. MacMillan & Co., New York. 1938.
2. Hartman, F. O., and Howlett, F. S. An analysis of the fruit characteristics of seedlings of Rome Beauty, Gallia Beauty, and Golden Delicious parentage. *Proc. Amer. Soc. Hort. Sci.* 40: 241–244. 1942.
3. Shay, J. R. Purdue University, LaFayette, Indiana. Personal Correspondence dated August 22, 1948.
4. Vincent, C. L., and Longley, L. E. Apple breeding in Idaho. *Idaho Agr. Exp. Sta. Res. Bul.* 8. 1930.
5. Wellington, Richard. An experiment in breeding apples, II. *N. Y. Agr. Exp. Sta. Tech. Bul.* 106. 1924.

# Inheritance of Susceptibility to Cedar-Apple Rust in Seedlings of Crab Apples

By F. C. Bradford, *U. S. Department of Agriculture, Glenn Dale, Md.*

THE season of 1947 at Glenn Dale, Maryland, was unusually favorable to infection by the cedar-apple fungus (*Gymnosporangium juniperi-virginianae* Schw.). Practically every one of perhaps 150 commercial seedlings of common apple was affected, though there was very little in about 950 budded trees, among which the seedlings stood. Among the varieties, Quaker Beauty (P. I. 148481), evidently a prunifolia hybrid, was affected most; lesser amounts were found on Northern Spy and Dabinett (P. I. 150648), and none at all on 17 other varieties, including Adam (P.I. 141867), Arrow (P.I. 148703), Bedford (P.I. 139668), Calros (P.I. 151253), Dolgo (P.I. 157047), Robin (P.I. 144025) and Sissipuk (P.I. 148500), all of which have more or less Eurasian crab in them. In no variety did infection of twigs occur and only in the seedlings was defoliation observed. In Crowell's (3) enumeration of varieties and their susceptibility, the progeny of the Eurasian crabs are not immune; out of 14 such hybrids listed, five, including Quaker Beauty, are listed as very or moderately susceptible. Of the native crabs and their hybrids, one (Anoka) is listed as slightly susceptible and one (Mercer County) as immune, while the others are reported as moderately or very susceptible. Moore (13) suggests division of apples into several classes, based on the resistance or susceptibility of their progenies to cedar-apple rust infection; he does not deal with crabs or crab hybrids.

The crab seedlings reported in this study resulted from crossing cider apples of England and France with Eurasian and with native crab apples, in an effort to produce apples that, while maintaining the astringency of the cider apple, would have more resistance to cold weather than the cider varieties (2). A few crosses were made with Red Astrachan, the most astringent of our common varieties and reported as resistant to cedar-apple fungus (3). The two native crabs used as female parents were Nevis, a pure form of *Malus ioensis,* and Kola, a hybrid between ioensis and common apple. Nevis (P.I. 127701) is a form of ioensis from its most north-westerly station (7) and was introduced by Hansen as an ornamental in 1930. It is a diploid. At Glenn Dale it has lost a few twigs from cedar-apple fungus in the course of 10 years. Kola (P.I. 127697) is a hybrid of ioensis from Elk River, Minnesota, fertilized with pollen of Duchess of Oldenburgh and was introduced by Hansen in 1922 (6). It is a tetraploid (7). In 10 years at Glenn Dale minor twig losses from cedar-apple rust have occurred.

The seed was sown in April 1947 in a cold frame and the records taken in September. All degrees of infection were counted alike, though there were very few cases which did not involve the trunk. In many cases of infestation at the ground level, the seedling died. Results with the native crab hybrids are shown in Table I.

TABLE I—INCIDENCE OF CEDAR APPLE RUST IN SEEDLINGS OF NATIVE CRAB

| Male Parent | | Female Parent | | | |
|---|---|---|---|---|---|
| | | Nevis | | Kola | |
| P.I. No. | | Number Seedlings | Infected | Number Seedlings | Infected |
| 105278 | Bulmer's Norman | 11 | 3 | 11 | 0 |
| 105517 | Moulin à Vent | 44 | 8 | 75 | 10 |
| 123734 | Bonté Normande | 47 | 16 | 8 | 1 |
| 132286 | Omont | — | — | 7 | 0 |
| 148147 | Red Astrachan | 7 | 0 | 5 | 0 |
| | Open pollinated | 45 | 11 | — | — |
| | Total | 154 | 38 | 106 | 11 |
| | Per cent infected | — | 24.6 | — | 10.7 |

Four crab apples with Eurasian ancestry were used. Filia (107 211) has the persistent calyx characteristic of *Malus prunifolia,* while Tayezhnoie (P.I. 107253) has the deciduous calyx that characterizes *M. baccata.* Tayezhnoie, whose name, which signifies "resister", was given because of its ability to withstand cold winters, is reputedly (11) a cross of Kandil Kitaika by *M. baccata.* Kandil Kitaika (P.I. 107-217) itself was a hybrid, but at Glenn Dale the material received under that name shows no sign of hybridity. Its hardiness in Russia is considerably lower than that of the other hybrids (15). Tayezhnoie is recommended as a rootstock in Russia (5) but in Maine it has proved incompatible when grafted with some varieties (9). It is claimed to have exceptional cold resistance (15) ; in fact, it is placed among the few most resistant (11). At Glenn Dale it has been among the most susceptible to fire blight.

Olga (P.I. 127702) originated with Hansen; it is a hybrid of Duchess of Oldenburgh x *Malus baccata f. cerasifera* (6). It has partly deciduous, partly persistent calyx lobes. At Glenn Dale its freedom from blight and its regularity of cropping, despite frosts which have killed the blossoms of most Eurasian crabs, have commended it. Since it is recommended as a trunk-former in Manitoba (10), it must possess hardiness above the average; in fact, its hardiness is above that of Hibernal (4, 14).

Rosthern No. 18 (P.I. 144027) is of Canadian origin and its endurance at Rosthern is guarantee of unusual winter hardiness. It was reported by Dr. M. B. Davis, Dominion Horticulturist, to have a "tannin" content entitling it to a place among astringent cider apples. At Glenn Dale, frost destroyed the crop in 1946, 1947 and 1948, and it has suffered from fireblight for 4 years. It is a clean, vigorous grower in the nursery.

Derived from *Malus baccata* and *M. prunifolia,* there were 105 seedlings from six crosses; of these only two, one of Olga and one of Tayezhnoie, were infected.

## LITERATURE CITED

1. BRADFORD, F. C. Nursery behavior of certain European apple varieties of prospective value as trunk-formers. *Proc. Amer. Soc. Hort. Sci.* 38:353–357. 1941.
2. ———— The beverage apples. *Fruit Prod. Jour.* 27:4:107–111. 1947.

3. CROWELL, IVAN H. Compilation of reports on the relative susceptibility of orchard varieties of apple to the cedar-apple rust disease. *Proc. Amer. Soc. Hort. Sci.* 32: 261–272. 1935.
4. CHIPMAN, G. F. The million dollar apple. *Country Guide (Manitoba)* 27: 12: 5, 22. 1934.
5. GORSHKOV, I. S. The choice of rootstocks (transl. title) Fruits and vegetables. Moscow. 1938. No. 4 pp. 45–46 in *Hort. Abstracts* 8: No. 2. 1938.
6. HANSEN, N. E. Plant introductions. *S. D. Agr. Exp. Sta. Bul.* 224. 1927.
7. ———— Fruits old and new, and northern plant novelties. *S. D. Agr. Exp. Sta. Bul.* 309. 1937.
8. ———— New hardy fruits for the northwest. *S. D. Agr. Exp. Sta. Bul.* 339. 1940.
9. HILBORN, M. T. Fight winter-kill with hardy apple stocks. *Amer. Fruit Grower.* 67: 10: 9, 22, 24–25. 1947.
10. LESLIE, W. R. Dominion Experimental Station, Morden, Manitoba. Results of experiments 1931–1937. Ottawa. 1938.
11. MICHURIN, I. V. Itogi polu vekovykh robot II Moscow and Leningrad. 1932.
12. Michurin Fruit Res. Inst. Frost damage to orchards and its repair. *Michurin Fruit Res. Inst.* Seljhosgiz, Moscow. 1944.
13. MOORE, ROBERT, C. A study of the inheritance of susceptibility and resistance to apple cedar rust. *Proc. Amer. Soc. Hort. Sci.* 37: 242–244. 1940.
14. RICHARDS, J. C. The Olga crab. *Country Guide (Manitoba)* 61: 8: 20. 1942.
15. ZAETS, V. K. Frost resistance of Michurin varieties of apple (transl. title). *Sady I. Ogorody No.* 6. 1941.

# Starting Seedlings of Montmorency Cherry

By LEON HAVIS and ANNA L. GILKESON, *Plant Industry Station, Beltsville, Md.*

IN order to conduct a satisfactory breeding program with cherries where Montmorency is to be used as a parent, it was first necessary to learn how to obtain a high percentage of seed germination and good plants. A brief report of the results on such a study in 1947 and 1948 is given here.

The Montmorency cherry seeds were obtained from a canning plant in southern Pennsylvania in July 1947. Any flesh remaining on the stones was removed by use of water under pressure from a sprayer. Care was taken to avoid any drying of the seed before the treatments were started. All seeds were stored at 36 degrees F for after-ripening. The agar cultures were made according to Tukey's method (1). The principal seed treatments were:

1. Nutrient-agar cultures, stones and seed coats removed.
2. Nutrient-agar cultures, only stones removed.
3. Planted in sand and muck in flats and stored for 2 to 8 months, kept moist, stones removed before planting.
4. Same as No. 3 except stones left intact.
5. Seeds stored dry for 2 to 8 months and planted in flats after removal from storage, stones removed before planting.
6. Same as No. 5 except stones left intact.

In the process of cracking the stones, there was danger of mechanical injury to the seeds. A method of cracking whereby usually no harm is done to the seeds consists in using pliers with a stop preventing them from shutting beyond a safe point. A limited test in which seeds were allowed to dry a few days until they had shrunk a little helped reduce cracking injury without reducing their viability. These seeds were soaked over night in running water before placing them in agar culture bottles for storage.

Seeds from all treatments were removed for germination tests at monthly intervals beginning after 2 months in storage. One flat containing 150 seeds was used at each period. The agar treatments were continued until the eleventh month and the sand-muck treatments until the eighth month after they were placed in storage. In order to have results on a comparable basis the data are presented here largely in terms of percentage of seedlings which reached a stage at which they could be well transplanted from flats or agar cultures to 4-inch plots, approximately 1½ inches high.

## RESULTS

The results of the nutrient-agar treatments indicated that the seed coats should not be removed, because when they were removed there was (a) occasional mechanical injury to the embryos, (b) increase in contamination in the agar, and (c) possibly more rapid drying of embryos in comparison with the treatments in which the seed coats were not removed. The germination and growth of plants to a

transplantable stage following the monthly removals from storage were usually much higher for the embryos whose seed coats were allowed to remain on the seeds. In some cases the seeds germinated but the seedlings failed to develop on the agar in the bottles to a transplantable size. The seeds with seed coats intact in the agar cultures gave approximately 25 per cent germination but no transplantable seedlings after either 2 or 3 months in storage (treatment 2, Table I). After 4 months 10 per cent reached transplantable size. From the fifth through the eighth month of storage, there was little difference in results for the different lengths of storage period, and an average of 88 per cent reached transplantable size during these periods. After the nineth month, although the germination continued high, there was unaccountable reduction in percentage of transplantable seedlings. Where the seed coats were removed before placing the seeds on the agar about one-half germinated after 2 months of storage, but only 17 per cent reached transplantable size. There was little increase after longer (5 months) storage, however, and a total average of only 22 per cent became transplantable seedlings (treatment 1, Table I). An unaccountable increase in percentage of good seedlings was noted after 9 months of storage in this treatment in which seed coats were removed.

Where the flats containing the cherry seeds were kept moist in storage and with the stones removed (treatment 3) 10 per cent were transplantable after 2 months in storage, and 20 per cent after 3 months. After that period there was little variation and the average was approximately 40 per cent. In the treatment where the storage media was kept moist and the stones left intact, there was much higher germination percentage. Here approximately 6 per cent were transplantable after 2 months of storage, but in spite of some damping-off difficulty, an average of 71 per cent were transplantable from the fifth to the eighth month (Table I).

The seeds that were stored dry and then planted in the mixture of sand and muck with their stones intact, did not germinate after any of the different lengths of time in storage. In limited tests in which the stones were removed after being stored dry, only the 3-month storage period yielded any plants at all and then only 10 per cent.

TABLE I—EFFECT OF SEED TREATMENT AND LENGTH OF STORAGE (36 DEGREES F) ON PERCENTAGE OF TRANSPLANTABLE CHERRY SEEDLINGS

| Seed Storage Treatment | Per Cent Transplanted After Different Storage Periods | | | |
|---|---|---|---|---|
| | 2 Months | 3 Months | 4 Months | 5 to 8 Months (Ave)* |
| 1. Agar culture—seed coats removed | 17 | 10 | 11 | 22† |
| 2. Agar culture—only stones removed | 0 | 0 | 10 | 88† |
| 3. Moist sand and muck—stones removed | 10 | 20 | 40 | 40 |
| 4. Moist sand and muck—stones intact | 6 | 75 | — | 71 |
| 5. Stored dry—stones removed at planting | 0 | 10 | 0 | 0 |
| 6. Stored dry—stones intact at planting | 0 | 0 | 0 | 0 |

*Differences between storage periods not significant after fifth month; therefore, only the average for those stored more than 5 months presented.

†Average of 5th to 11th month.

From these results, it seems that nutrient-agar culture is preferable for small numbers of Montmorency cherry seeds since a higher percentage of transplantable seedlings were obtained with such culture than with the sand and muck medium. To avoid injury to embryos in removal of stones, drying the seeds in the stones for about 3 days at room temperature in order to slightly shrink the seeds was found desirable. Then, after removing the stones, the seeds should be soaked in running water over night before being placed in the nutrient agar. Evidently the seed coats should not be removed, and the storage period should probably be at least 5 months at 36 degrees F.

Apparently, where seed supply is not limited, satisfactory germination and growth may be expected if seeds are stored at 36 degrees F with stones intact in a moist medium such as sand and muck for at least 3 months. Current tests indicate that a storage period of 5 months is more reliable. It seems essential that the seeds be kept moist during storage.

## Literature Cited

1. Tukey, H. B. Artificial culture methods for isolated embryos of deciduous fruits. *Proc. Amer. Soc. Hort. Sci.* 32: 313–322. 1935.

# The Use of Malus Species For Apple Rootstocks

By KARL SAX, *The Arnold Arboretum, Harvard University, Jamaica Plain, Mass.*

IN our apple breeding program at the Arnold Arboretum we have found that some of the Asiatic species of apples are apomictic and breed true from seed even when pollinated by other species. In one case the cross between two sexually reproduced species produced an $F_1$ which was apomictic. These apomictic species have been used as rootstocks for commercial apple varieties with the hope that they might be of value in controlling tree growth and age of fruiting.

Of the various Asiatic species tested, *Malus hupehensis, M. toringoides,* and *M. sikkimensis* proved to be apomictic. *Malus Tschonoskii* produces very uniform progeny, presumably due to absence of cross pollination with other species, and not due to apomixis. The same is probably true of *M. florentina* from Italy. The apomictic hybrid is a cross between *M. astracanica* and *M. Sargenti.*

With the exception of *Malus florentina* all of these species are moderately hardy (zones 4 or 5), have good root systems, and are immune or resistant to crown gall. When the seed is started in the greenhouse and the seedlings are set out in the nursery about May 15th, most of the trees are large enough to bud by late August.

In 1940 a few seedlings of *Malus Tschonoskii, M. hupehensis, M. toringoides* and *M. sikkimensis* were budded with McIntosh. Since only five to ten seedlings of each species were budded, adequate statistical records are not available, nor did we then have the necessary space for comparing growth rates of these trees with those on standard seedling stocks. However, the 1-year whips were vigorous and relatively uniform in all cases. Subsequent growth of these trees shows definite differences in rootstock effects.

McIntosh on *Malus toringoides* produces a nearly standard tree in both size and shape. The *M. hupehensis* rootstock is semi-dwarfing and the trees lack vigor. McIntosh on *M. Tschonoskii* forms a very smooth graft union, but growth is poor. The most promising results were obtained by budding McIntosh on *M. sikkimensis.* This rootstock produces a semi-dwarf tree with a spreading growth habit. The stock is somewhat larger than the scion at point of union. It is probable that this combination will produce mature trees that are from one-half to two-thirds of the standard size. *Malus sikkimensis* merits testing as a rootstock with different varieties and in different localities. We have budded the standard New England varieties on *M. sikkimensis* for testing at our Case estate, and have distributed seed to a number of experiment stations in this country where rootstock studies are being conducted.

*Malus florentina* produces very uniform seedlings, but growth is slow and few survive after several years in our nurseries. Yet when budded on *M. sikkimensis* seedlings they make more growth in a single season than they do on their own roots in four years. Apparently the weak root system is responsible for the poor growth of this species. We have had similar results with lilac hybrids which grew poorly on their own roots, but did well on tree lilac roots.

McIntosh budded on *Malus florentina* has produced very small precocious 2-year-old trees. This species may be worth testing as a dwarfing stock in a milder climate or when used as an intermediate stock.

During the past few years we have used a number of *Malus* species for rootstocks. Although these seedlings were not grown for a comparison of growth rates, there are definite differences in uniformity. The data are shown in Table I. The first four lots are sexually reproduced seedlings. The commercial seedlings were graded, but after another year's growth in the nursery showed considerable variability. The 3747 hybrid seedlings were cut back for comparison with the same seedlings budded on *M. toringoides*. In both cases the roots were 2-years-old and the tops 1-year-old. The *M. honanensis* and *M. astracanica* seedlings were measured at the end of the first year's growth. The coefficient of variability for trunk diameter of these sexually reproduced seedlings ranges from 26 to 37.

TABLE I—VARIATION IN HETEROZYGOUS AND HOMOZYGOUS APPLE SEEDLINGS AND ROOTSTOCK EFFECTS

| | Trunk Diameter (Mm) | | | | | | | | | | | | | n | m | c v. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | |
| *Malus Honanensis*. . | 2 | 4 | 10 | 7 | 7 | 11 | 3 | 4 | 2 | — | — | — | — | 50 | 5.8 | 37 ± 2.8 |
| 3747 C.B . . . . . . . | — | — | 2 | 4 | 2 | 3 | 6 | 6 | 3 | 2 | 1 | 0 | 2 | 31 | 8.2 | 32 ± 2.9 |
| Commercial . . . . . | — | 3 | 6 | 5 | 8 | 15 | 5 | 6 | 2 | — | — | — | — | 50 | 6.5 | 28 ± 2.0 |
| *Malus astracanica* . | — | 3 | 5 | 13 | 14 | 14 | 16 | 11 | 6 | 1 | 1 | — | — | 84 | 7.0 | 26 ± 1.4 |
| *Malus sikkimensis* . . | — | 4 | 4 | 6 | 16 | 26 | 25 | 17 | 2 | — | — | — | — | 100 | 7.1 | 22 ± 1.1 |
| *Malus toringoides* C.B. | 1 | 0 | 5 | 9 | 15 | 5 | 5 | — | — | — | — | — | — | 40 | 5.8 | 22 ± 1.7 |
| 19039/*Sikkimensis*. . . | — | — | — | — | 2 | 3 | 5 | 5 | 7 | 3 | 4 | 1 | — | 30 | 9.4 | 19 ± 1.6 |
| 3747/*Toringoides*. . . | — | — | — | — | 8 | 6 | 5 | 7 | 5 | — | — | — | — | 31 | 7.8 | 17 ± 1.5 |

The apomictic rootstocks include 1-year-old *Malus sikkimensis* seedlings, *M. toringoides* cut back at the beginning of the second year's growth, a clonal ornamental variety 19039 on *M. sikkimensis* and 3747 seedlings budded on *M. toringoides*. All are more uniform than the sexually reproduced seedlings. The greater uniformity of the budded trees versus the seedlings could perhaps be attributed to some selection in budding by eliminating the smallest seedlings. Most striking is the greater variation of the 3747 hybrid seedlings on their own roots as compared with the same trees on *M. toringoides* roots.

Since the clonal rootstocks are more uniform than are sexually reproduced seedlings, one might expect greater uniformity of trees propagated on clonal stock or on their own roots. Comparisons of growth and yield of apple trees on clonal stocks compared with those on heterozygous seedling stocks, as shown by many workers, have shown a greater uniformity of trees on their own roots or on clonal stocks in some cases, but in general there seems to be little consistent effect in reducing variability as measured either by tree size or fruit yields.

Apomictic species of *Malus* produce more uniform seedlings than do sexually reproduced seedlings. Some of these apomictic species may be of value as rootstocks for cultivated varieties of apples. If suitable types are found the reproduction of "clonal" rootstocks by seed offers certain advantages over propagation by layering or cuttings.

# Germination Trials on Open Pollinated Peach Pits from the 1945 Crop of Named Varieties and Seedling Selections[1]

By George D. Oberle,[2] *Virginia Agricultural Experiment Station, Blacksburg, Va.*, and H. O. Bennett,[3] *Geneva, N. Y.*

The peach breeding program conducted at the New York State Agricultural Experiment Station gave the opportunity for growing a large number of peach seedlings from open pollinated seed. Pits from 45 varieties were included in the study. These included some of the more recently introduced varieties as well as many of the standard commercial varieties. Data were collected concerning the formation of sound kernels, proportion of kernels germinating and production of strong seedlings. Nurserymen often have difficulty in getting a good stand of peach seedlings for use as budding stock in the nursery, even when normally developed seed is used. Peach breeders have found great variation in the germinability of peach seed of different maternal origins. In view of the wide range of varieties studied and the variable results obtained from the different varieties it seemed desirable to report these findings.

## Materials and Methods

Peach pits to the number of 40,706 were collected from 45 varieties during the ripening season of 1945. The trees furnishing these pits were growing in the testing orchard of the New York State Agricultural Experiment Station at Geneva, New York. Only two to four trees of each variety are included in the planting. Several colonies of bees were located in an adjoining orchard. Weather conditions during the blossoming season were favorable for bee flight and activity, thus providing ample opportunity for cross pollination in the variety test orchard.

The fruits in all cases, with but four exceptions to be mentioned later, were harvested at a tree-ripe stage and the pits were removed from the flesh within a day or two after harvesting. The pits were washed and dried at room temperatures and then stored at once in a cold storage room held at 34 degrees F to reduce the amount of drying of the embryos or kernels. Early in January the pits were packed in damp sawdust in bushel baskets and stored in a nursery cellar in which the temperature was held within the range of 35 to 40 degrees F. The sawdust was watered whenever inspection indicated that it was desirable. After a stratification period of 12 weeks the pits were cracked with a mechanical nut cracker and the kernels removed.

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[1]This paper is a progress report of part of the tree fruit breeding program of the New York State Agricultural Experiment Station, Geneva, New York and is published as Journal Paper No. 775, New York State Agricultural Experiment Station, Geneva, New York.

[2]Formerly Associate Professor of Pomology, New York State Agricultural Experiment Station.

[3]Formerly Agent, U. S. Department of Agriculture, Bureau of Plant Industry, New York State Agricultural Experiment Station.

The kernels were held in a moist condition at 34 degrees F until soil and weather conditions permitted planting in the nursery. The kernels were planted April 29, 1946 in a fine sandy loam soil well adapted to nursery use. Furrows were opened with a hand plow and the kernels were dropped at a spacing of 2 inches in rows which were spaced at 42 inches. The kernels were covered with an inch of soil, which was loose and friable and permitted ready emergence of the seedlings.

The kernels germinated quickly and the young seedlings soon emerged. Early growth was satisfactory but as the season progressed it became evident that the light sandy loam was deficient in available nitrogen. In late July a light side dressing of ammonium nitrate was applied to which the seedlings made rapid response. On August 22, counts were made in the nursery on all of the seedlings and notes were taken on the relative vigor of the different populations. The data presented in Tables I to III inclusive, were taken from the counts made when the pits were saved, when the pits were cracked and when the trees were evaluated in the nursery.

In general the seedlings were considered to have made good growth with most of the seedlings averaging 2½ to 3 feet in height on August 22. Less variation in height of seedlings and vigor of growth was observed than had been expected in view of the wide range of seed parents included in the study. The only populations noted as being above or below the general average of the entire planting relative to size, vigor and uniformity were the following:

J. H. Hale and Veteran—outstanding in vigor and uniformity of seedlings.
Sullivan and Goldfinch—slightly above the average in vigor.
Hardee—healthy and uniform but growth was somewhat dwarfed.
Ideal—many seedlings were weak and spindly.
New York Station No. 303, Marigold and Greensboro—most seedlings lacked vigor.
Golden Jubilee—most seedlings appeared weak during the early stages of growth. Many failed to survive but those which did survive were of average vigor when the counts were made.

Table I lists the varieties used as seed parents arranged in order of percentage of seedlings produced on the basis of the number of pits saved. The time of ripening as compared to Elberta is shown in the second column of the table. The number of pits saved from each variety shows the size of the population on which the percentage figures are based. The percentage of good kernels from the pits saved presents a measure of the amount of embryo abortion prevailing in these varieties during the 1945 season and also a measure of the tendency for certain varieties to produce more than one well filled kernel per pit. The percentage of surviving seedlings based on the number of pits saved gives an indication of what might be expected in number of seedlings from planting a given number of pits of any of the varieties included in the study. The percentage of seedlings based on the number of good kernels presents a measure of the

TABLE I—PEACH SEEDLING PRODUCTION FROM OPEN-POLLINATED SEED OF NAMED VARIETIES ARRANGED IN ORDER OF PARENTAGE OF SEEDLINGS PRODUCED BASED ON THE NUMBER OF PITS SAVED

| Seed Parent | Days Ripe Before Elberta** | Number of Pits Saved | Per Cent of Sound Kernels | Per Cent of Seedlings Based on Pits Saved | Per Cent of Seedlings Based on Sound Kernels Planted |
|---|---|---|---|---|---|
| Veteran | 14 | 194 | 192.2 | 98.9 | 51.4 |
| Kalhaven | 4 | 257 | 104.2 | 77.7 | 74.6 |
| J. H. Hale | + 1 | 421 | 92.8 | 76.4 | 82.3 |
| Elberta | — | 672 | 100.9 | 72.4 | 71.8 |
| Tornado | + 2 | 604 | 106.9 | 66.6 | 62.3 |
| McAllister Wonder | 2 | 684 | 111.1 | 66.0 | 59.4 |
| Early Elberta | 5 | 648 | 96.9 | 62.9 | 65.0 |
| Rosebud | 33 | 621 | 92.7 | 60.0 | 64.7 |
| Goldfinch | 20 | 1,429 | 120.6 | 59 2 | 49.1 |
| Burbank July Elberta | 16 | 160 | 139.3 | 55.5 | 49.3 |
| Champion | 9 | 165 | 180.0 | 54.5 | 30.3 |
| Morse No. 1 | 13 | 3,322 | 99.6 | 49.1 | 49.3 |
| Summercrest | 10 | 1,173 | 107.6 | 47.7 | 44 0 |
| Dewson | 16 | 274 | 110.9 | 47.4 | 39.1 |
| Eclipse | 19 | 1,970 | 104.1 | 46.1 | 44.3 |
| Viceroy* | 20 | 385 | 130.9 | 44.9 | 34.3 |
| Hardee | 1 | 272 | 83.8 | 42.6 | 48.6 |
| Sullivan | + 3 | 172 | 81.9 | 41.2 | 50.0 |
| Sunglo | 13 | 583 | 98.6 | 38.8 | 43.1 |
| Sungold | 3 | 702 | 102.5 | 38 4 | 37.5 |
| Zarn | 16 | 258 | 95.3 | 38.3 | 40.0 |
| Vedette* | 19 | 2,056 | 124.3 | 34.8 | 28 0 |
| Raritan Rose | 28 | 1,300 | 87.2 | 34.8 | 39.9 |
| Prolific | 5 | 300 | 103.6 | 33.0 | 31.1 |
| Station No. 303 | 14 | 733 | 92.0 | 31.7 | 34.5 |
| Early Crawford | 7 | 968 | 91.5 | 31.3 | 35.4 |
| Halehaven | 14 | 657 | 102.1 | 29.5 | 28.9 |
| Carman | 18 | 281 | 70.7 | 27.4 | 34.8 |
| Golden Jubilee | 26 | 2,253 | 100.8 | 26.4 | 26.2 |
| Delicious | 21 | 373 | 106.4 | 25.7 | 24.1 |
| Cumberland | 29 | 486 | 76.6 | 25.5 | 32.0 |
| Sunbeam | 32 | 1,233 | 103.0 | 25.3 | 24.4 |
| Valiant* | 16 | 1,505 | 89.5 | 24.0 | 26.8 |
| Armstrong No. 1 | 9 | 313 | 113.7 | 22.3 | 19.7 |
| Kathryn | 21 | 502 | 91.5 | 21.5 | 23.5 |
| Oriole | 30 | 1,721 | 97.9 | 20.9 | 20.8 |
| Golden Globe | 19 | 608 | 77.9 | 16.9 | 21.7 |
| South Haven | 17 | 228 | 87.7 | 16.2 | 18.5 |
| Station No. 306 | 25 | 495 | 71.9 | 15.7 | 21.9 |
| Ideal | 13 | 415 | 72.7 | 12.4 | 17.2 |
| Marigold | 37 | 1,353 | 53.5 | 1.8 | 3.8 |
| Greensboro | 43 | 511 | 11.1 | 0.4 | 3.4 |
| Mikado | 44 | 100 | 0.0 | 0.0 | 0.0 |
| Lola Seedling | 41 | 100 | 0.0 | 0.0 | 0.0 |
| Arp Beauty | 37 | 100 | 0.0 | 0.0 | 0.0 |

*May have given poorer stands of seedlings because of less favorable location in the nursery.
**A plus (+) sign denotes number of days after Elberta.

germination and survival under field conditions of sound kernels of the varieties studied.

The fifth column of Table I presents the percentage of seedlings produced by each variety on the basis of the number of pits saved arranged in order from highest to lowest. As has been shown by numerous other workers in general, the pits from late ripening varieties produced a higher portion of seedlings than the pits from early season varieties. However, some exceptions to this were observed. Rosebud, a very early season, white-fleshed peach ranks near the top of the list as does Goldfinch. Such exceptions probably result from the tendency for a high proportion of the pits of these varieties to have more than one sound kernel per pit. Other varieties showing that tendency include Veteran, Champion, July Elberta and Vedette. On the other hand, such midseason varieties as Halehaven, Ideal

and South Haven, which gave rather low percentages of seedlings, probably have genetic weaknesses which are responsible. These varieties have been observed to produce poor stands of seedlings, at Geneva, from seed of known pollen parentage.

The proportion of seedlings produced by each variety on the basis of sound kernels planted in shown in the last column of Table I. These figures reflect the tendency of certain varieties to produce more than one sound kernel per pit.

TABLE II—PER CENT PRODUCTION OF SEEDLINGS FROM PEACH PITS FROM FRUITS PICKED AT THE NORMAL STAGE COMPARED WITH THOSE FROM FRUITS ALLOWED TO DROP

| Seed Parent | Treatment of Fruit | No. of Pits | Seedlings (Per Cent) |
|---|---|---|---|
| Sunbeam | Hand picked | 1,233 | 25.3 |
| Sunbeam | Drops | 967 | 13.6 |
| Raritan Rose | Hand picked | 1,300 | 34.8 |
| Raritan Rose | Drops | 497 | 11.8 |
| Golden Jubilee | Hand picked | 2,253 | 26.4 |
| Golden Jubilee | Drops | 695 | 10.6 |
| Zarn | Hand picked | 258 | 38.3 |
| Zarn | Drops | 132 | 8.3 |

Another phase of the study was to determine whether the degree of ripeness of the fruit at the time of harvest had any influence on the production of seedlings. Pits were saved from paired trees of each of four varieties of peaches. One tree of each variety was harvested when the fruit was in a soft ripe stage suitable for immediate use. The fruit on the other tree of each variety was allowed to ripen on the tree until it dropped to the ground.This fruit was gathered after all of the fruits had dropped by which time many had rotted. The pits were removed from the fruit and handled in the same manner as the other pits used in this study. Table II shows the proportion of seedlings produced from the pits.

These data show that peach pits from fruits that were allowed to drop produced significantly smaller proportions of seedlings than pits from fruits that were hand picked. The authors believe that the decreased germination and production of seedlings from the pits of dropped fruits resulted from fungus invasion of the kernels, which were noticeably moldy and decayed at the time the pits were cracked.

A study was made of the effect of possible cross pollination on the seedling production from pits of known female parentage. One lot of Elberta peach pits from a large commercial orchard made up of trees of Elberta only and separated from orchards having other varieties by a fourth of a mile was collected and handled in comparable manner as the lots already reported upon. Table III presents the data comparing the production of seedlings from pits from this solid planting of Elberta with those from Elberta grown in the station orchard where there was ample opportunity for cross pollination.

A germination test conducted in the laboratory under controlled conditions showed that 71 per cent of the Elberta kernels from the solid block were capable of germination. However, many of the seedlings were weak and survived only a short time after germination.

TABLE III—SEEDLING PRODUCTION FROM PITS OF ELBERTA FROM A MIXED PLANTING AND FROM A SOLID BLOCK

| | Elberta From Mixed Planting | Elberta From Solid Block |
|---|---|---|
| No. of pits | 672 | 1,754 |
| Seedlings produced (as per cent of pits planted) | 72.4 | 47.9 |

This is reflected by the low percentage of trees surviving in the nursery at the time the count was made. The authors interpret these data as signifying that most of the embryos from the solid block of Elbertas were of self pollinated origin, which would probably result in production of some genetically weak offspring. The pits from the mixed planting, on the other hand, probably resulted to a large extent, from cross pollination and hence gave rise to a large proportion of vigorous seedlings.

## SUMMARY

1. Seedlings were grown from 40,706 pits from 45 varieties of peaches collected during the 1945 harvest season and planted in the nursery in 1946.

2. Seedling counts were made August 22, 1946 and showed that pits from varieties ripening less than 30 days before Elberta generally give better stands of seedlings than pits from varieties ripening earlier. Rosebud was an exception to this.

3. Many varieties produced more than one sound kernel per pit. Among these were Veteran, Champion, July Elberta, Viceroy, Vedette and Goldfinch.

4. Some varieties, which ripen in midseason or later such as Halehaven, Ideal, and South Haven gave poor stands of seedlings verifying observations of previous years.

5. Pits from fruits that were allowed to drop from the trees were found to give poorer stands of seedlings that pits from hand picked fruits.

6. Elberta pits from a solid block of this variety gave a poorer stand than Elberta pits from a mixed planting that offered ample opportunity for cross pollination.

# The Effects of Certain Pruning Practices and Wound Dressings on Callusing of Tree Wound

By L. C. Chadwick and E. E. Nank, *Ohio State University, Columbus, Ohio*

Pruning of ornamental shade trees is an old and well established art. Yet, few of the practices commonly performed are based on experimental data that indicates these practices are the best from the standpoint of the rate and effectiveness of wound healing. The practitioner may need to remove certain definite branches, even though the wound caused by the removal of a nearby branch might callus much faster. Nevertheless, it is important that data be compiled on the effect of size, health and location of the branch, among other factors, on wound healing. This project was undertaken to study these factors, along with the effect of certain wound dressings on callus development.

Tilford (6) found that bordeaux-linseed oil paint when applied to fresh cut wounds retarded callus formation, especially during the first year. Although it is highly fungicidal, it is not considered a satisfactory general purpose wound dressing. He also found asphaltum, one of the most satisfactory wound dressings, consistently stimulated callus formation during the first year following wounding and treatment and prevented checking and cracking of the wood which is often the forerunner of decay.

Collins (1) reports that bordeaux-linseed oil paint has been used extensively with good results, but he recommends that it be used as a temporary dressing only since it weathers rapidly. He found that asphalt emulsions were good but some have the disadvantage of cracking and flaking-off over a period of time.

Welch and MacDaniels (7) in testing the durability of wound dressings found that shellac was practically gone from the wound surface in a year following application, and the wood was badly checked. They also report that bordeaux dressings are somewhat toxic resulting in consistent cambial injury and an increase in the wound area. Orange shellac and asphalt paints showed no appreciable effect upon callusing.

Cooley (2) tested several wound dressings and found that shellac treated wounds were the only ones that callused better than the untreated wounds. This was particularly evident the first and second seasons.

Marshall (4) found that there was no lasting effect from applications of shellac, but the initial healing was stimulated. Shellac is least beneficial when applied to wounds made in the spring and may even retard callus development during this period. He found the protective coat of shellac to be thin and very apt to crack under stresses of contraction and expansion of the tree. Marshall noted that water emulsions of asphalt are valuable for covering wet surfaces. He reports that if asphalt is applied in thick coatings it is very likely to stimulate decay rather than retard it. He found bordeaux dressings satisfactory

for protecting wounds against infection and decay, but it will not penetrate bark or wood sufficiently to destroy fungi mycelium that is already established. It is somewhat porous, does not blister but will not adhere to wet wood. It appears to have a somewhat retarding effect on callus growth.

Howe (3) observed the healing of fruit tree wounds treated with shellac, white lead, yellow ochre, white zinc and avenarius carbolineum. He reports impaired healing with all treatments except shellac.

## Materials and Methods

This study of the effect of pruning practices and wound dressings on callusing was started in the fall of 1941. All wounds were made at this time by the removal of limbs and not by making artificial cuts in the trunk of a tree as has been customary with most previous wound treatment experiment. An average of 12 limbs were removed from each of 13 trees of English elm, *Ulmus procera*. In all, 160 wounds were made, which ranged from 2 to 12 inches in diameter. The trees were located in a grove, spaced 15 to 25 feet apart and were approximately 25 to 35 feet in height and 8 to 12 inches in diameter.

The following data was taken on each tree or limb removed: 1, health of the tree; 2, position of the tree in relation to others in the grove; 3, position of the branch removed in respect to height from the ground, direction facing and its relation to other nearby branches; 4, health of the branch removed, described as (a) dead, (b) poor growth, (c) good growth or (d) vigorous growth; 5, angle of the branch to the trunk; and 6, size of the wound.

Immediately after the limb was removed, the wound area was traced on graph paper. Each year following the original wounding, the unhealed area was retraced and in this way the rate of healing, as measured with a planimeter, could be calculated in square inches. In some cases wound areas increased in size due to cambial die-back. Increases in wound size were recorded as negative square inches.

In addition to three commercial tree paints[1], Toch Brothers paint, Sav-a-tree paint and Leonard's paint, Bordeaux-linseed oil paint and orange shellac were used as the wound dressings. These different paints were selected because they had been reported from various sources to be effective tree wound dressings and because they varied considerably in their nature or composition. Since previous reports had indicated some differences in respect to the time dressings were applied, the time of application was varied in this experiment. Dressings were applied (a) as soon as the wound was made, (b) after 1 or 2 days, and (c) after 3 to 5 days. On a limited number of wounds, shellac was applied at once, with one of the other dressings applied to the same wounds 5 to 7 days later.

Plans of the experiment called for all treatments to be applied to each tree and for the treatments to be replicated at least five times.

[1]The Toch Brothers paint was obtained from Toch Brothers Co., 386 Fourth Avenue, New York City, the Sav-a-tree paint from Southport Paint Co., Savannah, Georgia, and the Leonard's paint from A. M. Leonard and Sons Co., Piqua, Ohio.

This plan could not be followed exactly because of variations in tree growth. Not all the treatments could be applied to each tree but considering all the trees each treatment was replicated from six to 12 times.

Wounds were retreated twice during the experiment. In the fall of 1942, at the time the measurements were taken, the wound areas which had increased in size were reshaped, the lips of dead wood removed and the uncallused area repainted with the same permanent paint as originally applied. In the fall of 1943 any flaky or blistered paint on the uncallused area was scraped-off and the uncallused area redressed with the original permanent paint.

Final measurements on the wound areas were made in the fall of 1944 after three growing seasons.

## Results and Discussion

*Effect of Certain Wound Dressings on Callusing:*—The results in Table I, based on similar sizes and location of wounds, show that the highest rate of callusing per wound as calculated at the end of the third growing season, occurred where orange shellac was applied. The wounds dressed with orange shellac showed that 90.45 per cent of the original wound area was callused. The poorest healing resulted where Sav-a-tree was applied. Leonard's, Toch Brothers and the bordeaux-linseed oil paints were intermediate in their effect on callusing.

The data recorded at the end of the first year show a similar relationship between the effectiveness of the different wound dressings as reported in Table I for the 3-year period. Wounds treated with

TABLE I—Effect of Different Types of Wound Dressings on Callusing

| Wound Dressing | Number of Wounds Treated | Per Cent of the Total Wound Surface Callused at the End of the Third Season |
|---|---|---|
| 1. Orange shellac | 15 | 90.45 |
| 2. Leonard's paint | 37 | 85.89 |
| 3. Toch Brothers paint | 37 | 81.51 |
| 4. Bordeaux-linseed oil | 34 | 79.08 |
| 5. Sav-a-tree paint | 38 | 76.70 |

Leonard's paint showed the highest percentage of callusing, followed by Toch Brothers, orange shellac, Sav-a-tree and bordeaux-linseed oil paints.

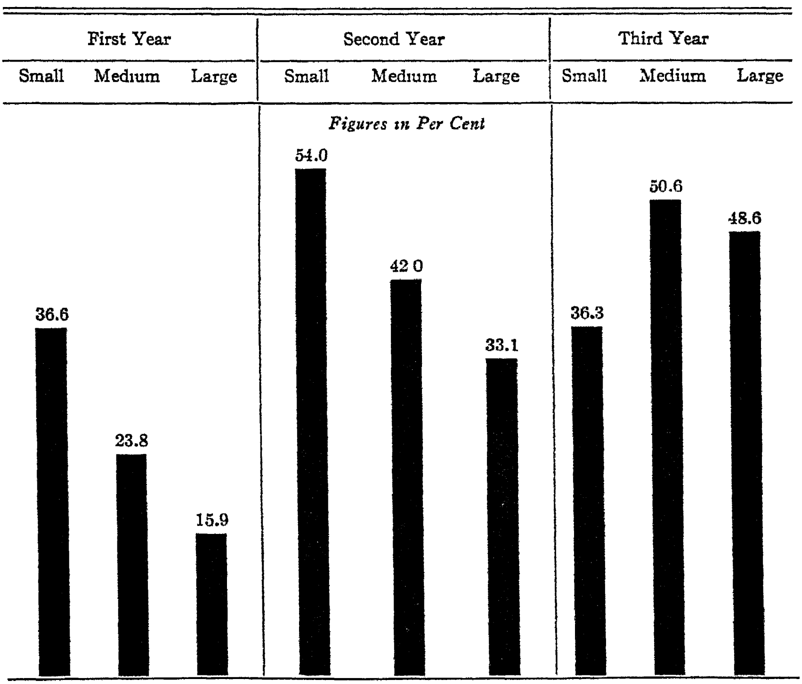
The rate and extent of callus growth on wounds treated with orange shellac was particularly satisfactory, especially on the smaller wounds. Some cracking and peeling resulted, but it was not extensive. It is easily applied and appeared to have no retarding effect on callus development. Applications would need replenishing at least once a year on large wounds. This was especially true for the medium and smaller sized wounds. It spreads with greater difficulty than several of the other paints used and considerable peeling resulted during the first and second years after application.

Toch Brothers paint gave good results on all sizes of wounds. It

spreads well and little peeling was noted. The bordeaux-linseed oil paint was not satisfactory. It was hard to apply and considerable peeling resulted. Observations indicated that to be effective wounds would need to be repainted at least twice a year. The Sav-a-tree paint seemed to retard callus growth, especially on the smaller wounds. It is easy to spread and peels very little.

*The Rate of Callusing in Relation to Wound Size:*—Wounds were classified into three size groups. Small wounds averaged 5.68 square inches each, medium sized wounds averaged 14.75 square inches, and large wounds averaged 29.28 square inches. Data on the rate of healing each year in relation to wound size are given in Table II.

TABLE II—RELATIVE PER CENT OF CALLUSING FOR THE FIRST, SECOND, AND THIRD YEARS IN RELATION TO ORIGINAL WOUND SIZE*




| *Wound Size | | Number of Wounds |
|---|---|---|
| Small | 5.68 square inches | 63 |
| Medium | 14.75 square inches | 59 |
| Large | 29.28 square inches | 38 |

At the end of the first year following wounding it was found that the relative per cent of callusing was greatest on the smaller wounds. This seems to be due to greater cambial activity about the circumference of the small wounds. In support of this statement, E. R. Roth (5) found that small wounds callused faster, not because they had less area to cover, but because they were healing at a faster rate. A similar correlation between rate of healing and wound size was apparent at

the end of the second year but it did not hold when the data for the third year growth was calculated. The amount of callus produced per unit on small wounds at the end of the third year, instead of being nearly double that of the large wounds as occurred the first and second years, was only two-thirds that of the larger wounds. What apparently happens, as the smaller wounds near complete coverage, the callus activity is slowed down. This may be due to compression of the callus rolls as they contact each other.

*The Rate of Callusing in Relation to the Angle of the Limb to the Trunk:*—The angle of the limb removed to the main axis or trunk was recorded and correlated with the amount of callus produced during a 3-year period. The average per cent of healing of 29 wounds made by removal of limbs that grew at near right angles to the trunk was 93.20 per cent, while only 71.13 per cent callusing occurred on the 27 wounds made by the removal of limbs that grew at acute angles to the trunk.

Usually the greater the angle between the main axis and the limb, up to and including 90 to 100 degrees, the stronger will be the subtended branch. The more acute the angle the weaker will be the crotch. Such weak unions are due to restricted cambium and adjoining tissue activity in the pinched area of the crotch. This restricted tissue activity will persist after removal of the limb, especially if a lip remains, and callusing is hindered. In commercial practice such wounds are shaped or pointed at the top to remove this congested tissue area, thereby stimulating more rapid callusing.

*The Rate of Callusing in Relation to the Direction the Wound Faces:*—Irrespective of the original wound size or wound dressing applied, the results of these experiments indicate that there is a tendency of wounds facing south or southwest to callus more rapidly than those facing north or northwest (Table III). In calculating the measurements of 39 wounds which faced southwest or south, it was found that the average callusing per wound was 85.68 per cent of the original wound area, while with the 35 wounds facing either north or northwest the average callusing per wound was only 74.35 per cent. This more rapid callusing of wounds facing south or southwest is probably due to temperature differences, especially during the early spring and possibly the fall months.

*The Rate of Callusing in Relation to the Height of the Wound in the Tree:*—Irrespective of the size of the original wound area or the

TABLE III—RATE OF CALLUSING IN RELATION TO THE DIRECTION THE WOUND FACES (AVERAGE PER CENT CALLUSING AT THE END OF THE THIRD YEAR)

| Direction | Number of Wounds | Per Cent |
|---|---|---|
| Southwest | 20 | 87.37 |
| South | 19 | 83.91 |
| Northeast | 14 | 82.31 |
| East | 15 | 80.82 |
| Southeast | 26 | 80.30 |
| West | 23 | 80.08 |
| North | 15 | 76.68 |
| Northwest | 20 | 72.60 |

dressing applied, data indicate that the higher the wound is in the tree, the more rapid will be the callus development. Evaluation of 62 wounds, 11 feet or over above ground level, showed an average callusing of 89.77 per cent at the end of the 3-year period. The average callusing of 66 wounds between 6 and 11 feet above ground level was 78.35 per cent, while that of 29 wounds below 6 feet was 73.44 per cent per wound. Such differences in rate of callusing in relation to the height of the wound in the tree may be explained in part, at least, by the greater proportion of large wounds at the lower levels and by light, temperature, food supply and growth activity at the different levels.

*The Rate of Callusing in Relation to Health and Vigor of the Tree:*—The factor of tree vigor is clearly exemplified in the rate of callus development. Of 11 original wounds made in 1941 on Tree F, which was of poor health, eight increased in area the first year. This increase in wound area averaged 11.4 per cent based on the original size of the wound. On a healthy tree nearby, only one wound out of 11 increased in area. The 10 remaining wounds callused approximately 30 per cent during the first growing season. R. P. Marshall (4) found that wounds on vigorous trees formed as much callus growth the first part of the first growing season as had wounds on the poorest trees at the end of the second growing season. It may be noted that data compiled show no direct correlation between fluxing and rate of callus development.

It is interesting to note that the data indicate somewhat better callusing of wounds made by the removal of dead or dying limbs over those made by the removal of live limbs. Callus growth over a 3-year period was recorded for 20 wounds made by the removal of dead or dying limbs and for a similar number made by the removal of live limbs. Average callusing of the wounds made by the removal of dead or dying limbs was 92.64 per cent, while callusing of wounds made by the removal of live limbs amounted to 88.97 per cent. This difference in rate of callusing may be due to a natural pinching-off of the dead limb by the cambium and adjoining tissues and a pre-orientation of the vascular elements around the limb, thus affording more rapid callusing of such wounds once the dead limb is removed.

*Effect of Time Interval Between Pruning and Application of the Wound Dressing:*—Data compiled failed to indicate the existence of any definite correlation of the time interval between the time of pruning and the application of the wound dressing and the rate of callus development. If there was a trend in any direction it favored a delay of 3 to 5 days after making the pruning cut before the wound dressing was applied. Such a practice would not be feasible commercially.

An initial coat of orange shellac previous to applying one of the other wound dressings used did not affect the extent of callus development over a 3-year period. Consequently, such a practice would not seem justified.

## Summary

1. This paper concerns a study of the effect of some pruning practices and certain wound dressings on the rate of callusing. All

wounds were made by the removal of limbs. An average of 12 limbs were removed from each of 13 trees of *Ulmus procera,* English elm. In all, 160 wounds were made ranging from 2 to 12 inches in diameter. In addition to three commercial tree paints, Toch Brothers, Sav-a-tree and Leonard's, bordeaux-linseed oil paint and orange shellac were used as wound dressings.

2. Wounds treated with orange shellac callused more rapidly than those treated with any of the other dressings. Wounds treated with Sav-a-tree paint callused the slowest.

3. Smaller wounds produce more callus per square inch of wound area than larger wounds. This appears to be due to greater cambial activity on the smaller wounds.

4. Wounds made by the removal of limbs that grew at nearly right angles to the main axis or trunk callused more rapidly than those wounds made by the removal of limbs which grew at acute angles to the main axis or trunk.

5. Irrespective of the original wound size or wound dressing applied, data indicate a more rapid healing of wounds facing south and southwest than wounds facing north and northwest. Wounds facing other directions were intermediate in rate of callusing.

6. Data compiled indicate that the higher the wound in the tree, the more rapid the callusing.

7. Wounds made on healthy, vigorous trees callused much more rapidly than those made on trees in poor health. Better callusing occurred on wounds made by the removal of dead or dying branches than those made by the removal of live branches. No direct correlation between fluxing and rate of callus development was apparent.

8. Whether the wound dressing was applied immediately following the pruning cut or after a delay of 1 to 7 days, did not appear to influence the rate of callusing. There appeared to be no advantage of applying a temporary dressing of orange shellac to be followed later by a more permanent wound dressing.

## Literature Cited

1. Collins, J. F. Treatment and care of tree wounds. *U.S.D.A. Farmers' Bul.* 1726: 1–38. 1934.
2. Cooley, J. S. Wound dressings on apple trees. *U.S.D.A. Cir.* 656: 1–19. 1942.
3. Howe, G. H. Effect of various dressings on pruning wounds of fruit trees. *N. Y. Agr. Exp. Sta. Bul.* 396: 83–94. 1915.
4. Marshall, R. P. The relation of season of wounding and shellacking to callus formation in tree wounds. *U.S.D.A. Tech. Bul.* 246: 1–30. 1931.
5. Roth, E. R. Wounds and decay by removing large companion sprouts of oaks. *Arborists News* 8: No. 7. 1943.
6. Tilford, P. E. Tree wound dressing. *Proc. Nat'l Shade Tree Conf.* 16: 41–54. 1940.
7. Welch, D. S., and MacDaniels, L. H. Apple tree pruning wounds. *N. Y. (Cornell) Agr. Exp. Sta. Bul.* 821: 1–23. 1945.

# The Wound Healing of Trees as Affected by Plant Growth Regulating Substances[1]

By EDWIN A. DAVIS, *Osborn Botanical Laboratory, Yale University, New Haven, Conn.*

IN THE REGION of injured tissues a complexity of chemical and physical changes take place. Cellular decomposition products are formed from the dead and necrotic cells which diffuse into the surrounding area. Also, cells adjacent to the wounded area increase in metabolic activity and commence to divide, giving rise to a mass of embryonic cells known as a callus. It was this association between the decomposition products from the degenerating cells and the meristematic activity in adjoining cells that led early workers to seek the cause of the increased metabolic activity in the products of decomposition (7). Haberlandt (3), after the work of the animal physiologist Starling (6), who first used the term hormone, and Fitting (2), who applied the term to plants, demonstrated the ability of cellular decomposition products to induce cell division and called the active component a wound hormone. Petrie (5) considered the wound hormone of Haberlandt to be an oxidation product of a compound normally inactive but which can be made active by atmospheric oxygen or by means of oxidases. He did not believe it should be classified as a plant hormone analogous to animal hormones. The term, however, has persisted and continues to be used very loosely and in many cases incorrectly.

The experimental portion of this paper deals with a study of the abilities of several plant growth regulating substances to stimulate wound healing. One of the compounds contains the sulfhydryl group which is considered by some to be in part responsible for this process, while the others are well known growth regulators and are able to control a varietiey of plant growth and developmental processes.

## MATERIALS AND METHODS

Four compounds, cysteine hydrochloride, αnaphthaleneacetic acid, 3–indolebutyric acid, and o–chlorophenoxyacetic acid were tested for their abilities to stimulate wound healing.[2] Lanolin was used as the carrier. The compounds were prepared in concentrations of 1, 10, and 50 mg/g lanolin. αNaphthaleneacetic acid, 3–indolebutyric acid and o–chlorophenoxyacetic acid were soluble in melted anhydrous lanolin (Mallinckrodt U.S.P. XI). The cysteine hydrochloride was insoluble in anhydrous lanolin but was soluble in the hydrous form (Mallinck-

[1]This work was supported by a grant from the F. A. Bartlett Tree Expert Company, Stamford, Connecticut.

The author wishes to express his deepest appreciation to Dr. Rush P. Marshall for his aid and encouragement during the course of this work and to the F. A. Bartlett Tree Expert Company for their generous support. Also, the author thanks Charles B. Davis for the tools which were used in this investigation.

[2]Samples of αnaphthaleneacetic acid, 3–indolebutyric acid, and o–chlorophenoxyacetic acid were obtained through the courtesy of The Dow Chemical Company, Midland, Michigan.

rodt U.S.P. grade). The preparations were made by dissolving the compounds in melted lanolin. Hydrous lanolin was used as a control for the cysteine preparations and anhydrous lanolin as a control for the others.

The experimental tree was the sugar maple, *Acer saccharum* Marsh. The trees were arranged in plots on the grounds of the Bartlett Tree Research Laboratories and had been used the previous year for a similar experiment. There were 120 trees, which were divided into four replications. The preparations containing the test compounds were assigned to the trees at random.

The wounds were elliptical in shape, wide in the middle, tapering to points at both ends. They were 15.5 square centimeters and were uniform throughout the experiment. Four wounds were made on each tree in most cases well above the wounds made the previous year. Three were test wounds and received the same treatment and one was a control. The wounds were arranged along the longitudinal axes of the trees in a spiral fashion, starting with the top wound facing north, east, south, and west. In each replication the control wounds faced in different directions and occupied different longitudinal positions in relation to the other wounds. The wounds were made with a specially designed tool. The bark was cut out in one piece and the surface of the wood was scraped in order to remove all cambial cells and phloem elements.

A ⅛ teaspoonful of Lanolin preparation was applied to each wound with a stiff bristled artist's brush. It was evenly distributed over the entire surface and was banked along the edge of the bark. Four hundred and eighty wounds were made. The wounds were prepared and treated between the dates June 16 and July 3, 1947. Readings for the determination of the amounts of healing were made the following March. Outlines of the areas of the wounds not healed over were traced on strips of celluloid. These outlines were traced on paper and their areas were measured with a planimeter. The areas for the three treatment wounds on each tree were averaged. The amounts of healing were determined by subtracting the areas not healed over from the initial wound areas.

An experiment was also performed in which solutions of 3-indolebutyric acid and cysteine hydrochloride were injected into the regions of cambial activity of overgrowths of old wounds of *Quercus borealis* Michx., to determine if the rate of healing could be accelerated by such a treatment. The wounds tapered to points at both ends and were originally used for cavity studies. They had healed over approximately 2 cm on each side at the middle portions. The compounds were prepared as water solutions at 100 mg/1. The right side of each wound received injections while the left sides served as controls. The solutions were injected into the region of cambial activity by means of capillary tubes (Fig. 1). These solutions were added to the wide necked portions of the injection tubes and allowed to drain into the tissues. Three 0.5 ml portions were injected into the wound overgrowths at three injection points four different times. The injections were spaced approximately 1 week apart starting August

4 and ending August 25, 1947. Ten wounds, each on separate trees were used. Five wounds were treated with 3–indolebutyric acid and five with cysteine hydrochloride. The number of millimeters of overgrowth extending over the wounds at the central portions were measured before and after the injections.

## RESULTS

The results of the first experiment are presented in Table I. They are expressed as the differences between the amounts of healing of the treatment and of the control wounds. Plus values indicate stimulation and negative values inhibition. Where there was complete tissue dieback the amount of healing is expressed as zero.

Cysteine hydrochloride was not found to stimulate healing at the concentration 1 mg/g lanolin. The concentrations 10 and 50 mg/g did, however, appear to be stimulatory. An analysis of variance did not indicate these concentrations to stimulate healing to a significantly greater degree than the concentration 1 mg/g. Also, the healing of wounds treated with cysteine at 10 and 50 mg/g was not found to be significantly greater than the healing of control wounds. For 19 degrees of freedom the t value is less than the value for significance at the 5 per cent point by the amount 0.08. This difference is very small and a larger number of pairs would have undoubtedly indicated the stimulation to be significant. It is, therefore, concluded that cysteine probably does have the property of stimulating wound healing. Further tests should be made, however, to confirm this.

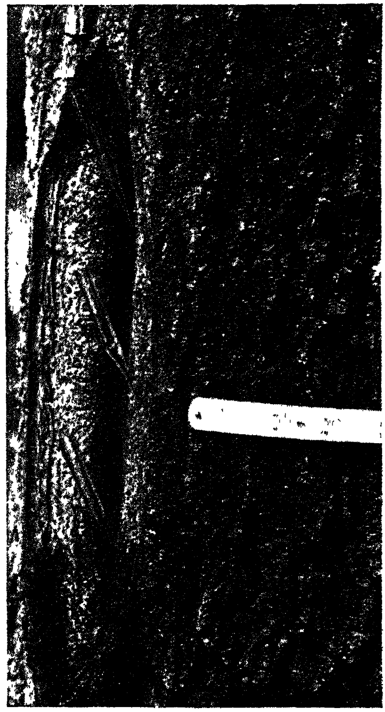


FIG. 1. Method of injecting chemicals into wound overgrowths of *Quercus borealis*.

$\alpha$Naphthaleneacetic acid did not stimulate healing at the concentrations tested. It was highly inhibitory and caused dieback at all of the concentrations although to a greater extent at 10 and 50 mg/g than at 1 mg/g.

3–Indolebutyric acid was likewise inhibitory at all of the concentrations and caused dieback at 50 mg/g.

o–Chlorophenoxyacetic acid did not prove to stimulate healing significantly at the concentrations tested. While the stimulation observed at 10 mg/g is not significant it is possible that further tests

TABLE I—THE HEALING OF SUGAR MAPLE WOUNDS TREATED WITH GROWTH SUBSTANCES IN LANOLIN

| Concentration (Mg/g) | Area Healed Over (Sq Cm) | | Difference (Sq Cm) | Concentration (Mg/g) | Area Healed Over (Sq Cm) | | Difference (Sq Cm) |
|---|---|---|---|---|---|---|---|
| | Treatment | Control | | | Treatment | Control | |
| | *Cysteine hydrochloride* | | | | *α-Naphthaleneacetic Acid* | | |
| 1.0 | 4.7 | 4.1 | +0.6 | 1.0 | 0 | 4.5 | −4.5 |
| | 7.0 | 3.8 | +3.2 | | 1 6 | 6.8 | −5.2 |
| | 5.0 | 5.5 | −0.5 | | 0 | 0.5 | −0 5 |
| | 4.7 | 5.0 | −0.3 | | 0 | 4.3 | −4.3 |
| | 4.7 | 2.6 | +2.1 | | 1.4 | 3 8 | −2 4 |
| | 3 6 | 5.1 | −1.5 | | 2 4 | 5.6 | −3.2 |
| | 3.9 | 4.8 | −0.9 | | 0 | 0.1 | −0 1 |
| | 3.9 | 5.0 | −1.1 | | 0 2 | 0 | +0 2 |
| | 6.2 | 7.1 | −0.9 | | 1.0 | 8.7 | −7.7 |
| | 1.1 | 1.7 | −0.6 | | 0 | 5.1 | −5.1 |
| | 2.9 | 2 6 | +0.3 | | 0 | 8.5 | −8.5 |
| | 2.4 | 5.5 | −3.1 | | 0 | 4.3 | −4.3 |
| | | $\bar{X}$ = − 0.2 | | | | $\bar{X}$ = −3.8 | |
| 10.0 | 5.3 | 4.4 | +0.9 | 10.0 | 0 | 7.5 | −7.5 |
| | 2 4 | 5 5 | −3.1 | | 0 | 6.3 | −6.3 |
| | 3.1 | 4 2 | −1.1 | | 0 | 8.5 | −8.5 |
| | 3.4 | 1.1 | +2.3 | | 0 | 3.6 | −3.6 |
| | 3.2 | 1.6 | +1.6 | | 0 | 0.5 | −0 5 |
| | 4.5 | 2.2 | +2.3 | | 0 | 5.0 | −5.0 |
| | 3 0 | 3.2 | −0.2 | | 0 | 1.9 | −1.9 |
| | 4.2 | 5 3 | −1.1 | | 0 | 3.8 | −3.8 |
| | 5.7 | 3.8 | +1.9 | | 0 | 2.1 | −2.1 |
| | 4.1 | 3.9 | +0.2 | | 0 | 3.6 | −3 6 |
| | 0.8 | 0.3 | +0.5 | | 0 | 3.9 | −3.9 |
| | 3.6 | 2.9 | +0.6 | | 0 | 7.1 | −7.1 |
| | | $\bar{X}$ = +0.4 | | | | $\bar{X}$ = −4.5 | |
| 50.0 | 6.2 | 4.7 | +1.5 | 50.0 | 0 | 3.7 | −3.7 |
| | 4.0 | 3.2 | +0.8 | | 0 | 2.8 | −2.8 |
| | 1.9 | 2.1 | −0.2 | | 0 | 3.6 | −3.6 |
| | 1.1 | 0 | +1.1 | | 0 | 1.3 | −1.3 |
| | 7.9 | 1.7 | +6.2 | | 0 | 0.7 | −0.7 |
| | 4 7 | 4.2 | +0.5 | | 0 | 2.3 | −2.3 |
| | 1.8 | 2.2 | −0.4 | | 0 | 5.1 | −5.1 |
| | 4.4 | 2.1 | +2.3 | | 0 | 6.4 | −6.4 |
| | | $\bar{X}$ = +1.5 | | | | $\bar{X}$ = −3.2 | |
| | *3-Indolebutyric Acid* | | | | *o-Chlorophenoxyacetic Acid* | | |
| 1.0 | 0 | 2.2 | −2.2 | 1.0 | 4.9 | 5.6 | −0.7 |
| | 3.4 | 6.0 | −2.6 | | 3.1 | 3.4 | −0.3 |
| | 1.5 | 6.2 | −4.7 | | 1.5 | 0 | +1.5 |
| | 3.2 | 4.6 | −1.4 | | 4.0 | 1.8 | +2.2 |
| | 0.7 | 0.4 | +0.3 | | 3.3 | 0 | +3.3 |
| | 0 | 8.6 | −8.6 | | 3.5 | 4.0 | −0.5 |
| | 1.4 | 3.5 | −2.1 | | 1.6 | 0 | +1.6 |
| | 1 6 | 3.2 | −1.6 | | 4.2 | 7.0 | −2.8 |
| | 4.7 | 7.7 | −3.0 | | 6.1 | 4.8 | +1.3 |
| | 1.1 | 4.5 | −3.4 | | 1.5 | 4.1 | −2.6 |
| | 1.2 | 1.5 | −0.3 | | 3.0 | 0 | +3.0 |
| | 2.7 | 3.6 | −0.9 | | 1.1 | 4.2 | −3.1 |
| | | $\bar{X}$ = −2.5 | | | | $\bar{X}$ = +0.2 | |
| 10.0 | 4.0 | 3.5 | +0.5 | 10.0 | 3.6 | 2.8 | +0.8 |
| | 1.9 | 2.6 | −0.7 | | 1.7 | 0 | +1.7 |
| | 0.1 | 2.0 | −1.9 | | 2.3 | 0 | +2.3 |
| | 0 | 7.5 | −7.5 | | 2.5 | 5.3 | −2.8 |
| | 2.5 | 6.5 | −4.0 | | 2.9 | 0.8 | +2.1 |
| | 2.5 | 5.8 | −3.3 | | 3.3 | 5.0 | −1.7 |
| | 0.1 | 0.1 | 0 | | 1.2 | 0 | +1.2 |
| | 1.1 | 3.9 | −2.8 | | 4.5 | 3.8 | +0.7 |
| | | $\bar{X}$ = −2.5 | | | | $\bar{X}$ = +0.5 | |
| 50.0 | 1.4 | 0 | +1.4 | 50.0 | 5.2 | 5.7 | −0.5 |
| | 0 | 3.0 | −3.0 | | 1.3 | 1.6 | −0.3 |
| | 0 | 0 | 0 | | 0.8 | 3.2 | −2.4 |
| | 0 | 2.2 | −2.2 | | 0 | 1.1 | −1.1 |
| | 0 | 6.1 | −6.1 | | 3.9 | 4.3 | −0.4 |
| | 0 | 2.1 | −2.1 | | 4.9 | 5.4 | −0.5 |
| | 0 | 7.2 | −7.2 | | 1.6 | 2.5 | −0.9 |
| | 0 | 4.8 | −4.8 | | 3.3 | 4.8 | −1.5 |
| | | $\bar{X}$ = −3.0 | | | | $\bar{X}$ = −1.0 | |

TABLE II—THE GROWTH OF WOUND OVERGROWTHS OF *Quercus borealis* AS AFFECTED BY CYSTEINE HYDROCHLORIDE AND 3-INDOLEBUTYRIC ACID

| Compound | Concentration Mg/1 | Lateral Growth (Mm) | | Difference (Mm) |
|---|---|---|---|---|
| | | Treatment | Control | |
| Cysteine hydrochloride........ . .. | 100 | 5 | 3 | +2 |
| | | 3 | 3 | 0 |
| | | 2 | 5 | -3 |
| | | 3 | 3 | 0 |
| | | 5 | 3 | +2 |
| 3-Indolebutyric acid... ......... | 100 | 2 | 2 | 0 |
| | | 1 | 4 | -3 |
| | | 1 | 1 | 0 |
| | | 3 | 3 | 0 |
| | | 3 | 1 | +2 |

would indicate this treatment to be capable of stimulating healing. The highest concentration was inhibitory.

The results of the injection experiment were entirely negative (Table II). The amounts of lateral extension of the overgrowths which occurred at the middle portions of the two sides of each wound are recorded in millimeters. The results are expressed as the differences between the amounts of lateral growth of the treatment and of the control sides of the wounds. As before, plus values denote stimulation and negative values inhibition. The data indicate that cysteine hydrochloride and 3–indolebutyric acid at the concentration 100 mg/1 neither stimulated or inhibited the lateral extension of the wound overgrowths.

## DISCUSSION

Although none of the compounds tested markedly stimulated wound healing o–chlorophenoxyacetic acid and cysteine hydrochloride, a source of the sulfhydryl group, appeared to have a stimulating effect.

Hammett and Chapman (4) found a positive correlation between cell increase in number and —SH concentration in white bean roots and demonstrated the —SH group to be produced as a result of injury. They considered it as the only compound yet uncovered which fulfills the requirements of a wound hormone. The term hormone, however, is misleading and it should perhaps be more correctly termed as a wound substance. The fact that glutathione, a tripeptide containing the sulfhydryl group, was found to stimulate wound healing (1) and that cysteine also appears to accelerate this process, supports the findings of Hammett and Chapman and suggests that the —SH group is also involved in the wound healing process of trees.

While o–chlorophenoxyacetic acid did not significantly stimulate healing it is possible that a more extensive experiment would reveal it to be stimulatory. It is interesting that 3–indolebutyric acid and αnaphthaleneacetic acid inhibited wound healing, as both compounds are very common growth regulators and are able to stimulate and control a variety of plant growth processes.

Neither cysteine hydrochloride or 3–indolebutyric acid stimulated the cambial activity of wound overgrowths of *Quercus borealis*. The fact that 3–indolebutyric acid did not stimulate cambial activity is not surprising as it was found to inhibit wound healing. However,

such is not the case for cysteine as it was found to be stimulatory. The finding that the lateral extension of wound overgrowths was not inhibited by 3–indolebutyric acid and not stimulated by cysteine can be explained on the basis that the solutions were transported away from the areas of the wounds and were diluted to the point of ineffectiveness.

From a practical standpoint it is possible that —SH containing compounds and perhaps o–chlorophenoxyacetic acid would be of value in stimulating the wound healing of trees when incorporated in wound dressings.

## Summary

1. Four compounds, cysteine hydrochloride, αnaphthaleneacetic acid, 3–indolebutyric acid, and o–chlorophenoxyacetic acid were tested for their abilities to stimulate the wound healing of sugar maple.

2. It is concluded as being very likely that cysteine hydrochloride, which contains the —SH group, is able to stimulate wound healing.

3. While o–chlorophenoxyacetic acid did not accelerate healing to any great extent there is some indication that further experiments might reveal it to have a stimulating effect.

4. αNaphthaleneacetic acid and 3–indolebutyric acid inhibited wound healing.

5. Cysteine hydrochloride and 3–indolebutyric acid when injected into wound overgrowths of *Quercus borealis* did not stimulate cambial activity.

6. The practical application of incorporating —SH containing compounds in wound dressings is mentioned.

## Literature Cited

1. Davis, Edwin A. The effects of several plant growth regulators on the wound healing of sugar maple. In preparation.
2. Fitting, H. Weitere entwicklungsphysiologische Untersuchungen an Orchideenblüten. *Zeitschr. Bot.* 2:225–267. 1910.
3. Haberlandt, G. Culturversuche mit isolierten Pflanzenzellen. *Sitz. Ber. K. Akad. Wiss. Wien. Math. -nat Classe 111.* I:69–91. 1902.
4. Hammett, F. S., and Chapman, S. S. A correlation between sulfhydryl, mitosis, and cell growth in length in roots of Phaseolus vulgaris. *Growth* 2:297–302. 1938.
5. Petrie, L. Experienze sulla formazione del sughero delle ferrite. *Boll. Staz. Patol. Veg. (Florence)* 9:328–352. 1929.
6. Starling, E. H. Die chemische Koordination der Körpertatigkeiten. *Verh. Ges. Deutsch. Naturf. Ärzt., Stuttgart.* 78(1):246–260. 1906.
7. Wiesner, J. Die Elementarstrucktur und das Wachstum der lebenden Substanz. Wien. 1892.

# Inheritance in Seedlings of Vaccinium Constablaei × Vaccinium Ashei Variety Pecan

By W. T. Brightwell, *Coastal Plain Experiment Station, Tifton, Ga.*, George M. Darrow, *Plant Industry Station, Beltsville, Md.*, and O. J. Woodard, *Coastal Plain Experiment Station, Tifton, Ga.*

There is a definite need for improvement of the rabbiteye blueberry, *Vaccinium ashei* (Camp). The present varieties are generally well adapted to soil and climatic conditions but lack earliness, quality, and size. This species was crossed with *Vaccinium constablaei* (Camp) or Constable's blueberry.

Crosses of these hexaploid blueberry species were made at Beltsville, Maryland, in the spring of 1939. The seedlings were sent to Tifton, Georgia, in the fall of 1941 where they were set on a low, light, Plummer sandy loam soil. This cross was made with the object of obtaining a variety for the South which ripens earlier and over a shorter period of time, with smaller seed, and a more tender flesh than most varieties of *Vaccinium ashei.*

*Vaccinium ashei* is native along the Yellow River in West Florida, and the Satilla, Suwannee Ogeechee, Altamaha, Savannah, and other rivers in the lower Coastal Plain of southeastern Georgia. The berries are mainly black, with a tough skin; most have gritty flesh and large seeds; they are medium to small in size; and there is a long period, 90 to 120 days, between flowering and fruit maturity. The plants are 10 to 15 feet high and sucker over an area of 5 to 15 feet. It is easily grown under cultivation.

*Vaccinium constablaei* is native to the high mountains of western North Carolina. The fruits of this species generally have a light blue color, tender skin and flesh, a very good flavor, small seeds, large fruit for a wild blueberry, and a relatively short period between flowering and fruit maturity. The plants are mostly 5 to 7 feet high, and sucker over an area of 5 to 15 or more feet. Considerable difficulty has been experienced in growing plants of this species out of its natural habitat.

Although the Pecan is a black-fruited rabbiteye variety of rather poor flavor, it was the only variety of *Vaccinium ashei* available at the time. The selection of *Vaccinium constablaei* used was one selected by Dr. F. V. Coville, and it also was the only one available.

Data are recorded in Table I on height and spread of 56 seedlings of this cross, their vigor, mildew resistance, size of berries, color, and scar left when the berry is removed from the plant. The height and spread of plants are recorded in feet.

No seedling attained a perfect rating on more than two characters. Most of the plants made poor growth. The tallest plant was 7 feet in height and had a spread of 6 feet. Two plants had a height of 6 feet and a spread of 7 feet. One plant had a spread of only 1 foot, and seven of only 2 feet.

Of the 56 seedlings only 18 were rated 7 or above for vigor; while of 20 rabbiteye seedlings that were set at the same time as the *Vaccinium constablaei* x Pecan seedlings, all were vigorous, two rating 7, eight rating 8, eight rating 9, and two rating 10 in vigor.

TABLE I—Distribution of Seedlings

| Height | | Spread | Rating Index | Rating According to 1 to 10 Index* | | | | |
|---|---|---|---|---|---|---|---|---|
| Feet | Number | Number | | Vigor | Mildew Resistance | Berry Color | Berry Size | Berry Scar |
| 1 | — | 1 | 1 | 2 | 2 | 2 | 1 | — |
| 2 | 3 | 7 | 2 | 5 | 1 | 2 | 17 | — |
| 3 | 8 | 8 | 3 | 5 | 3 | 9 | 8 | — |
| 4 | 20 | 10 | 4 | 4 | 7 | 5 | 3 | 1 |
| 5 | 15 | 23 | 5 | 10 | 8 | 14 | 8 | 3 |
| 6 | 9 | 5 | 6 | 12 | 10 | 16 | 12 | 6 |
| 7 | 1 | 2 | 7 | 9 | 10 | 3 | 2 | 6 |
| 8 | — | — | 8 | 6 | 6 | 1 | 1 | 15 |
| 9 | — | — | 9 | 3 | 6 | — | — | 9 |
| 10 | — | — | 10 | — | 3 | — | — | 12 |

*Rating 1 = poorest, 10 = best, 6 = minimum of commercial value.

Resistance to leaf diseases is important since some rabbiteye plants are practically defoliated before the crop is harvested. Thirty-five or 67 per cent of the hybrid plants (Table I) were scored 6 or above on resistance to mildew, and 21 were 5 or below. This is much greater resistance than was shown in comparable rabbiteye seedlings in the same field.

Four of the hybrids had no fruit. Fruits of most of the other 52 seedlings were smaller than those of comparable rabbiteye seedlings. Thirty-two or 61 per cent were rated 5 or below and 20 were rated 6 or above.

A waxy bloom which gives the berry a blue color is desirable on berries for the fresh market. Berries that have a heavy bloom do not shrivel so quickly as those that do not have a heavy bloom and, therefore, present a more attractive appearance. Of the fruiting seedlings, only 15 or 28 per cent were scored 6 or above.

The scar is the injury to the berry where it is separated from the plant. It is important that the scar be small and dry so that the berries will not be wet and decay in transit. The berries on only four plants were scored 5 or below, and those on 48 or 92 per cent were scored 6 or more. Twelve were scored 10. Excellent shipping quality may be expected in this cross.

The berries from some plants were rated on flavor late in the season. Their quality was high. Berries from six plants were rated sweet; those from five plants were rated sweet and aromatic; those from five plants, sweet and flat; those from 12 plants, flat; berries from one plant were rated as acid; those from seven, as sub-acid; and those from three, as tart.

The most desirable qualities of the seedlings in this cross are their early maturity and small dry scar. The most undesirable qualities are the small size of berry, dark color, and lack of vigor of most of the plants. However, some seedlings of the desired qualities were obtained. Further crosses and back-crosses have been made in which the *Vaccinium ashei* varieties Walker and Myers and selections of previous crosses with *Vaccinium constablaei* and with selected $F_1$ hybrids. The aim is to improve flavor, size, and color, and to retain early ripening. By the use in breeding of superior varieties of *Vaccinium ashei* and of *Vaccinium constablaei* much better seedlings should be obtained.

# Control of Grasses in Raspberries by Fall, Spring and Summer Applications of Sodium Trichloroacetate[1]

By R. F. Carlson and J. E. Moulton, *Michigan State College, East Lansing, Mich.*

Quack grass (*Agropyron repens* L.) and Kentucky blue grass (*Poa pratensis* L.) often become established in the rows of older raspberry plantings. These grasses compete with raspberry plants for nutrients and moisture, and in addition, interfere with spraying and picking operations. The control of the grass weeds by mechanical means is almost impossible, especially where the hedge-row system is used. Therefore, if control could be obtained by a chemical spray, labor and cost of production would be reduced. Preliminary studies (1) made in 1947 under greenhouse conditions, indicated that TCA (Trichloroacetate)[2] could be used to control grasses if applied when the raspberry plants were dormant. On the basis of this work, actual field applications were made in November 1947, and in April and July 1948.

## Materials and Methods

These studies were made in Alpena county [3], in a 13-year -old planting of Latham raspberries badly infested with quack grass and Kentucky blue grass (Fig. 2, bottom). Sodium trichloroacetate readily dissolves in water and it was applied with a knapsack sprayer in aqueous solution at different rates per acre. The amounts of the material used in the different treatments were calculated on the basis of actual acetate. The area covered with the chemical was based on the area of row and not on total area of the field. The spray was directed toward the base of the canes so that the lower portion of the canes as well as the grass was thoroughly covered.

## Experimental Results

*Fall Applications:*—TCA was applied November 10 at the rates of 10, 30 and 60 pounds per acre. At this time the old canes had been removed and only the fruiting canes remained. These canes had shed their leaves and were in a dormant stage. The quack grass was green, appeared active, and averaged 10 to 12 inches in height. The soil was moist and a light snow followed the application.

When observations were made April 28, the following spring, there was no new growth of quack grass in the treated rows, while there was abundant growth of grass in the check rows (Fig. 1). Later, July 6, some weak growth of Kentucky blue grass and quack grass was present in the rows that received 10 pounds per acre, but

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[1]Journal Article No. 1000 (n.s.) of the Michigan Agricultural Experiment Station.

[2]The material for this work was supplied by the Dow Chemical Company, Midland, Michigan and E. I. duPont de Nemours and Company, Inc., Wilmington, Delaware.

[3]The authors acknowledge the cooperation of Ralph Trafelet, County Agricultural Agent, who selected the grower where the work was done and who also gave assistance in the work.

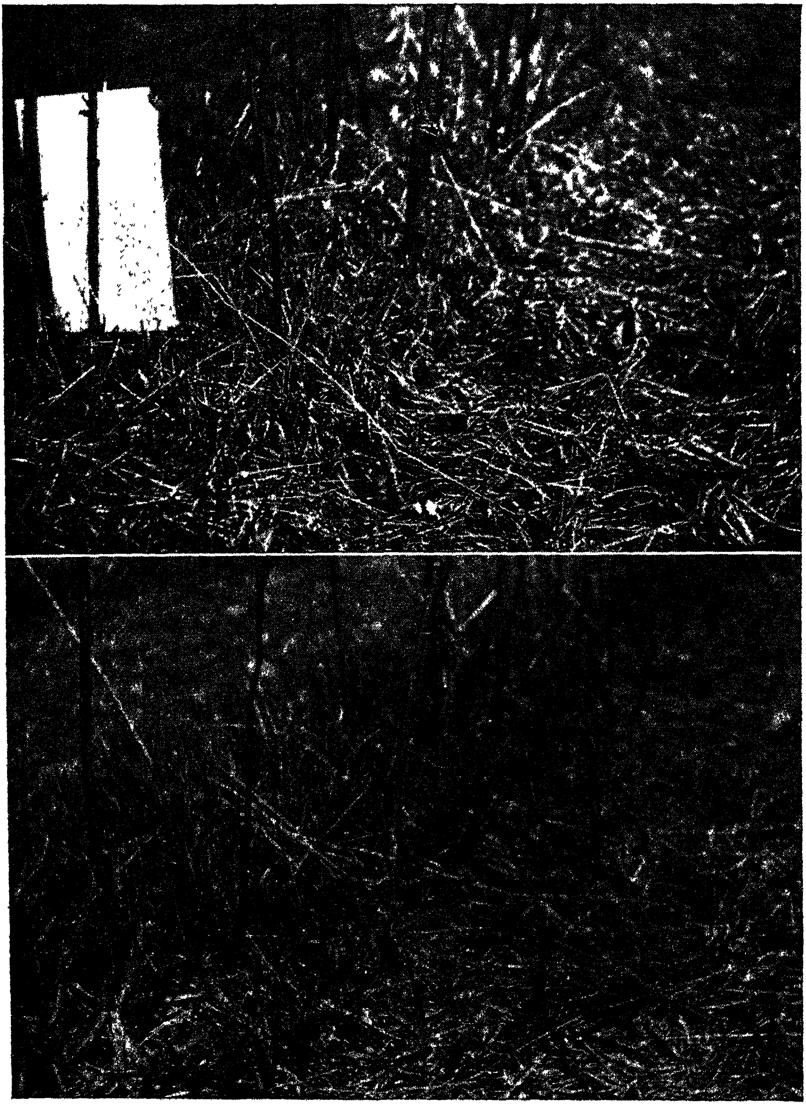

FIG. 1. Top: 30 pounds of TCA applied November 10, bottom: check. Note new growth of grass in the check row. Photographed April 28.

only Kentucky blue grass was found in the rows that received the 30-pound rate (Fig. 2). At the 60-pound rate there was complete control of both grasses. There were no apparent symptoms of injury on the canes in April, but in July the leaves on the fruiting canes and on "suckers" showed slight chlorosis between the veins. This was most noticeable on plants that received the highest rate per acre and very slight on the plants that received the lowest rate.

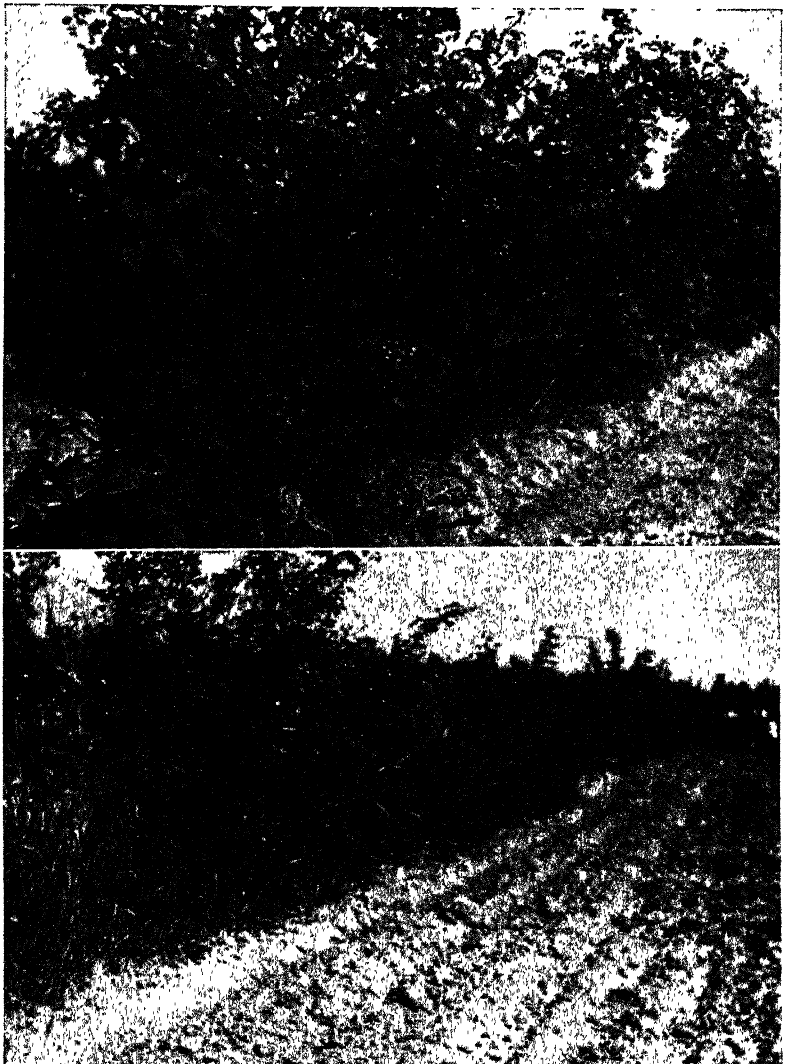

FIG. 2. Same treatment as shown in FIG. 1, but photographed July 6. Top: 30 pounds of TCA, bottom; check.

*Spring Application:*—On April 28, 1948 an application similar to the one in the fall was made. At this time the buds of the fruiting canes had started to break, that is, the buds were about ¼ inch long. The quack grass and Kentucky blue grass had produced new growth above the winter-killed grass as shown in the check rows (Fig 1). The results were similar to those obtained from the fall application, although

From these field observations it is not possible to tell whether the material was absorbed by the grasses through the roots or stem or both. Since some of the material got into the soil it is possible that some of the killing action came through the absorption of the material by the roots.

The fall and spring applications did not interfere with the production of fruit. This is based on the observations of the grower cooperating in these tests. It was noticed that the summer application interfered with the normal production of fruit, because the berries from treated areas were smaller than those from canes of the unsprayed rows.

Quack grass rhizomes were dug from all treatments for examination. The rhizomes from the rows that had been treated with 10 pounds of TCA per acre were not dead as was indicated by the presence of new shoots and normal buds, while the rhizomes from the 30-pound application had very few active shoots and buds. The rhizomes from the 60-pound application had no active shoots or bud and were apparently dead. This was true for all treatments, that is, fall, spring and summer applications.

The data presented in this paper is preliminary in nature and, therefore, is not intended for general recommendations. A follow-up study of the treated plants is needed in order to determine the possibility of delayed injury.

## Literature Cited

1. Carlson, R. F., and Moulton, J. E. Use of the ammonium salt of trichloroacetate, the sodium salt of trichloroacetate, ammonium thiocyanate, and herbicide "PB", in the eradication of grasses, and the effect of these chemicals on strawberry and raspberry plants. *Mich Agr. Exp. Sta. Quart. Bul.* 30: 413–421. 1948.

# Nutrient-Element Deficiency Symptoms of Muscadine Grapes in Sand Culture[1]

By T. B. HAGLER, *Alabama Polytechnic Institute, Auburn, Ala.* and L. E. SCOTT, *University of Maryland, College Park, Md.*

DURING the 1946–1947 seasons muscadine grapes *(Vitis rotundifolia)* growing in the experimental vineyard at Auburn, Alabama, exhibited unusual patterning of the leaves. These symptoms first appeared about mid-summer and became progressively more pronounced as the season advanced. Early symptoms showed interveinal chlorosis in the older leaves. Areas of yellow tissue were arranged in rather orderly manner between the veins. Necrotic spots appeared at the margin of old leaves and between the veins of the younger leaves. Since mineral nutrition studies with muscadine grapes are exceedingly meager, sand culture experiments were designed both as an aid in ascertaining the cause of the field condition described and to record the effects of mineral deficiencies.

The data herein presented concern the development of deficiency symptoms of nitrogen, phosphorus, potassium, calcium, magnesium and boron in the muscadine grape resulting from sand-culture experiments conducted in the horticultural greenhouses of the University of Maryland.

## MATERIALS AND METHODS

One-year-old layered vines of the varieties Dulcet and Hunt were carefully selected for uniformity of size and root development. The plants were washed thoroughly with tap water, and the roots were pruned to 6 or 8 inches in length.

On February 28, 1948, 60 vines of each variety were planted in 2-gallon glazed crocks filled with 18-mesh quartz sand, one plant per crock. Drainage was provided by covering the hole in the bottom of the crock with glass wool. The vines were pruned to five or six buds, and two canes were allowed to develop on each plant. After the vines had made 8 to 12 inches of growth, the pots were placed in a randomized block arrangement consisting of three replications, each block containing plants as uniform in size as was possible. Crocks were flushed daily for 7 days with tap water, and distilled water was used each day thereafter until April 14 when application of nutrient solutions was begun.

Eight nutrient treatments were used; check (no nutrients), full nutrients, and minus nitrogen, phosphorus, potassium, magnesium, calcium, boron.

The full-nutrient solution contained Baker's analyzed grade of salts as shown in Table I.

In addition to the solution micro elements were supplied in the form of a general supplementary solution containing Al, I, Br, Ti, Sn, Li, Mn, B, Zn, Cu, Ni, and Co based on the results of Hoagland and

[1]Scientific Paper No. A227 Contribution No. 2156 of the Maryland Agricultural Experiment Station (Department of Horticulture).

TABLE I—FULL NUTRIENT SOLUTION APPLIED TO MUSCADINE GRAPES GROWING IN SAND CULTURE

| Salts Used | Parts Per Million in Dilute Solution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | Cl | Na |
| $NH_4NO_3$ | 100 | — | — | — | — | — | — | — |
| $KH_2PO_4$ | — | 50 | 63 | — | — | — | — | — |
| $MgSO_4.7H_2O$ | — | — | — | — | 25 | 33 | — | — |
| $CaCl_2.2H_2O$ | — | — | — | 150 | — | — | 265 | — |
| $K_2SO_4$ | — | — | 37 | — | — | 15 | — | — |
| $Na_2SO_4$ | — | — | — | — | — | 26 | — | 37 |
| Totals | 100 | 50 | 100 | 150 | 25* | 74 | 265 | 37 |

*Changed to 50 p.p.m. on June 19.

Snyder (2). Iron citrate solution (0.5 per cent) was added in the proportion of 1 ml per liter of dilute solution.

Modifications of the full-nutrient solution, shown in Table II, were made in order to obtain the various mineral-deficient solutions.

TABLE II—MODIFICATIONS OF FULL-NUTRIENT SOLUTION TO OBTAIN MINERAL-DEFICIENT SOLUTIONS

| Mineral Deficiency Desired | Chemicals Omitted | Chemicals Substituted |
|---|---|---|
| Nitrogen | Ammonium nitrate | None |
| Phosphorus | Monopotassium phosphate<br>Sodium sulfate | None |
| Potassium | Monopotassium phosphate<br>Potassium sulfate | Monosodium phosphate |
| Calcium | Calcium chloride | Potassium chloride<br>Sodium chloride |
| Magnesium | Magnesium sulfate | None |
| Boron | | None |

Nutrient solutions were applied three times per week at the rate of 500 ml per crock, and each crock was flushed on other days with 500 ml of distilled water to prevent excess accumulation of salts.

Linear measurement of vine growth was taken once each week throughout the course of the experiment.

The data were analyzed by the use of the analysis of variance as outlined by Snedecor (5).

## RESULTS

### DEFICIENCY SYMPTOMS

The vines as a whole grew well and reacted quickly to the different treatments. There were little or no observed differences between varieties in the response to the various treatments. Development of characteristic symptoms by the vines in the deficiency series was especially noticeable. The appearance of deficiency symptoms is given in chronological order.

*Nitrogen:*—Nitrogen deficiency symptoms (Fig. 1) were apparent on the vines of the minus nitrogen series in both Dulcet and Hunt varieties on May 1, or about three weeks after growth had started. Both young and old leaves were lighter green and smaller than those receiving full nutrients.

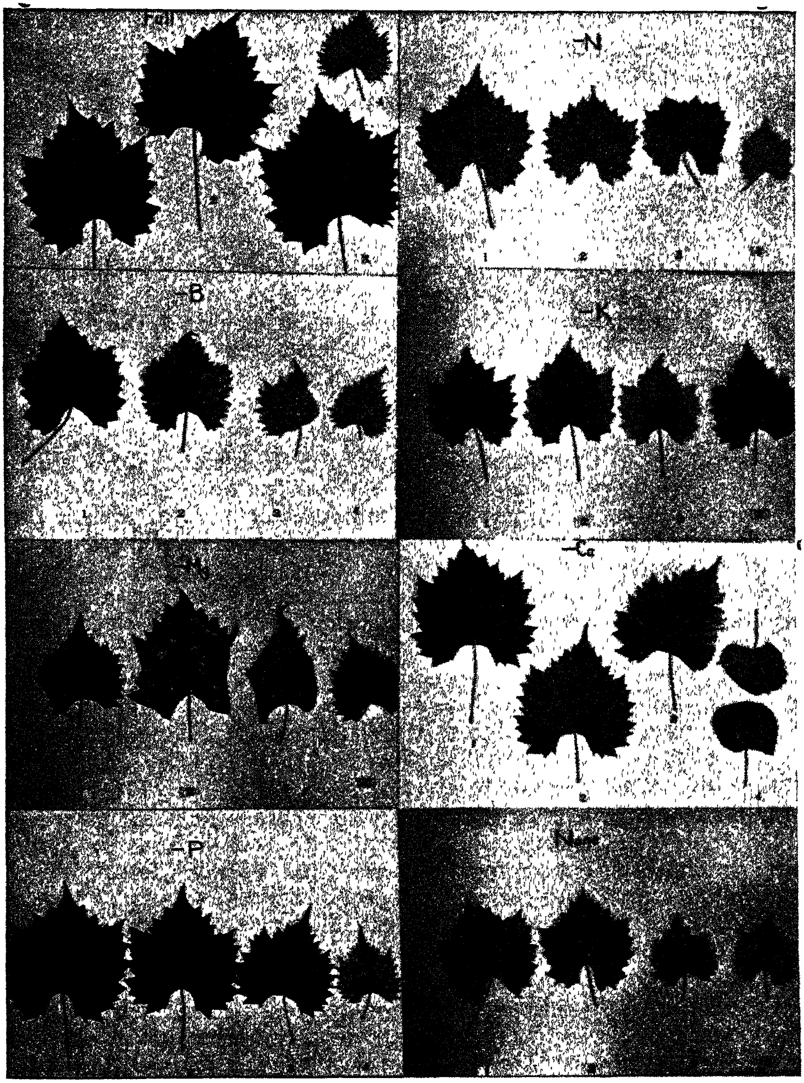

FIG. 1. Leaf deficiency symptoms of the Hunt muscadine grape when grown in sand cultures. (Leaf numbers indicate relative maturity of leaves: 1 — mature; 4 — immature).

*Boron:*—The first evidence of boron deficiency (Fig. 1) was observed on May 2. Symptoms in the early stages appeared as dark brown water-soaked areas in the apical tendrils. Further symptoms appeared rather abruptly. By May 4 many of the tendrils had begun to die back from the tips, and young leaves had begun to show a chlorosis and twisting. One week later terminal buds began to die. Necrotic

spots appeared in the old leaves during later stages of the deficiency symptoms. Scott and Schrader (4) did not observe deficiency symptoms developing on the lower leaves of bunch grapes even though the terminal parts were extremely affected. Young shoots had short internodes and were very brittle as compared with vines receiving full nutrients.

*Potassium:*—The first evidence of potassium deficiency appeared on May 6 as interveinal and marginal chlorosis of the fifth and sixth leaves from the base of the plant. Later symptoms consisted of development of necrotic pinhead spots throughout the older leaves followed by marginal scorching and yellowing (Fig. 1). Younger leaves developed a light green interveinal chlorosis followed by marginal scorching in extreme cases. These chlorotic leaves became quite glossy in appearance. Except for the glossy appearance of the younger leaves the potassium deficiency symptoms agree with those reported by Askew (1) on bunch grapes.

*Magnesium:*—Magnesium deficiency (Fig. 1) became evident about the same time as potassium. By May 9 the older leaves had developed interveinal chlorosis. Leaves from the middle of the vine toward the tip developed a water-soaked appearance followed by necrotic spots between the veins and puckering of the leaves. This burning appeared rather suddenly. Leaves of the middle portion of the vine abscissed leaving a bare area with older leaves below and young leaves above.

Symptoms appearing in the magnesium deficient series of treatments were very similar to those found in the field. It is evident that the interveinal chlorosis and necrosis appearing on bearing vines in the field were due to deficiencies of magnesium. These symptoms seemed to be very similar to those described by Lot (3).

*Calcium:*—The first evidence of calcium deficiency (Fig. 1) appeared about June 1. Young leaves developed interveinal and marginal chlorosis followed by necrotic pinhead spots near the margin of the leaf. Later these spots appeared between the veins. Affected leaves cupped inward. Necrotic areas appeared along the margin of young leaves, and many of them dropped off. There was considerable dieback of the tips of the vines. The stems of plants receiving no calcium were lighter green than those receiving full nutrients.

*Phosphorus:*—Deficiency symptoms developed much more slowly on the vines of the minus phosphorus series and were not as evident as those developed by vines deficient in the other elements. Leaves, leaf petioles and stems (Fig. 1) appeared darker green in color than those receiving full nutrients. Leaves were somewhat smaller than the full nutrient leaves. No chlorosis, necrosis, or foliar malformation was evident.

*No Nutrients:*—Vines receiving only distilled water throughout the course of the experiment first showed typical nitrogen deficiency symptoms followed by boron deficiency symptoms (Fig. 1). The only noticeable difference in the boron deficiency symptoms of this series and those from the minus boron treatments was the failure to develop laterals from axillary buds.

## Growth of Vines

Vines receiving full nutrients grew vigorously in the greenhouse and compared favorably with growth of 1-year-old layered vines in the field. All other treatments made significantly less growth than the full-nutrient treatment.

There was little or no difference in the linear growth of the vines in the minus nitrogen series and full nutrient when the first deficiency symptoms appeared. Maximum growth of the minus nitrogen series was reached by the first of June.

The minus potassium and minus magnesium series continued to make some vine growth each week. Vines of these treatments were much smaller in diameter than those of the full nutrient series.

Linear growth of the main shoots in the minus boron and minus calcium series stopped completely due to die-back of the growing tips. Lateral canes with short internodes developed from axillary buds. These laterals developed the characteristic die-back of the growing tips similar to the symptoms on the main canes.

Minus phosphorus vines made significantly less growth than those of the full nutrient series. However, these vines made very good growth when compared to 1-year-old vines under field conditions.

Vines receiving only distilled water stopped growing about May 1. They showed die-back of the growing tip similar to that exhibited by the minus boron series.

Weekly measurements of the shoots of each vine were made throughout the course of the experiment. This data is given in Table III.

TABLE III—Length of Shoot Growth Produced by 1-Year-Old Muscadine Grape Vines During 2 Months' Sand Culture in the Greenhouse

| Treatment | Variety | |
|---|---|---|
| | Dulcet (Cm) | Hunt (Cm) |
| Minus nitrogen | 119 | 56 |
| Minus phosphorus | 215 | 229 |
| Minus potassium | 167 | 149 |
| Minus calcium | 235 | 260 |
| Minus magnesium | 170 | 120 |
| Minus boron | 77 | 74 |
| Full nutrient | 310 | 318 |
| No nutrients | 47 | 38 |

L.S.D. at 5 per cent level 58; 1 per cent level 77.

F values for:

| | |
|---|---|
| Blocks | 8.75** |
| Treatments | 60.345.73** |
| Varieties | 0.54 |
| Treatment × varieties | 1.22 |

**Significant beyond the 1 per cent level.

## Summary

One-year-old layered vines of Dulcet and Hunt muscadine grapes were grown in sand media and supplied with different nutrient solutions.

Characteristic deficiency symptoms for nitrogen, phosphorus, potassium, calcium, magnesium and boron are described. Except for phosphorus these symptoms were sufficiently different to be easily identi-

fied. Deficiency symptoms appeared in the following order: nitrogen, boron, potassium, magnesium, calcium, and phosphorus.

There was a significant difference between the linear growth of vines receiving a full-nutrient solution and those receiving mineral-deficient solutions. Linear growth of the main shoots in the minus boron and minus calcium series stopped completely due to die-back of the terminal buds.

Vines receiving full nutrients grew well in the greenhouse in sand culture and compared favorably with the growth of 1-year-old layered vines in the field.

## Literature Cited

1. Askew, H. O. A case of combined potassium and boron deficiencies in grapes. *New Zealand Jour. Sci. and Tech.* 26 (3) (Sec. A): 146–152. 1944.
2. Hoagland, D. R., and Snyder, W. C. Nutrition of strawberry plant under controlled conditions: (a) Effects of boron and certain other elements: (b) Susceptibility of injury from sodium salts. *Proc. Amer. Soc. Hort. Sci.* 30: 288–294. 1933.
3. Lott, W. L. Magnesium injection in muscadine grape vines. *Proc. Amer. Soc. Hort. Sci.* 52: 283–288. 1948.
4. Scott, L. E., and Schrader, A. L. Effect of alternating conditions of boron nutrition upon growth and boron content of grape vines in sand culture. *Plant Phys.* 22 (4): 526–537. 1947.
5. Snedecor, George W. Statistical methods. The Iowa State College Press, Ames, Iowa. 1946.

# The Effect of Soil Management on the Yield of Cultivated Blueberries[1]

By Vladimir Shutak, E. P. Christopher, and Leona McElroy, *Rhode Island State College, Kingston, R. I.*

An expanding cultivated blueberry industry has increased the demand for cultural information.

There has been considerable work on the use of various mulching materials. Most investigators have found sawdust superior to other mulches. Savage and Darrow (5) found that looser forms of mulch, such as rye straw and oak leaves, are much better than clean cultivation, but not so good as sawdust. Chandler and Mason (1) found that mulch retains more soil moisture, keeping the mean above that for clean cultivation, it maintains a lower soil temperature, reduces the growth of blueberry plants in sandy soil, and increases growth in clay loam soil. Kramer *et al* (4) obtained increased yields of both highbush and dry-land blueberries with various mulches but mulching decreased plant survival of dry-land blueberries. They found twice as much soil moisture under mulches as in cultivated plots.

## Materials and Methods

Two-year old Pioneer blueberry plants were set out in the spring of 1942 on a well-drained Narragansett loam (2). All plants were grown in clean cultivation for one season, then a cover crop was planted in the fall and plowed under the following spring. The field was divided into 20 plots with six bushes in each, with buffer rows separating all plots. The four cultural treatments were: sawdust mulch, rye straw mulch, clean cultivation with covercrop planted in fall and plowed under in the spring, and clean cultivation throughout. The experiment was set up with randomized plots replicated five times. Differential treatments were started in the spring of 1943 and enough additional mulch material was applied each year to maintain a mulch 3 to 4 inches thick. All plants received uniform pruning and fertilizer applications. In the fall of 1947, bushes were severely pruned; this tended to equalize the crop, since larger bushes had greater amounts of wood removed. The bushes in sawdust and some in straw-mulched plots produced greater amounts of growth which made it necessary to thin them out considerably. Bushes in other treatments required less pruning and thinning.

For pH determinations two separate soil samples were taken, the first from 0 to 6 inches and the second from 6 to 12 inches. Samples from the upper 6 inches were taken for soil moisture determinations.

Soil temperatures were measured at the 6-inch level excluding the thickness of the mulch. Some temperature records were continuous for 6 days (taken with a Foxboro recorder) and some were made at intervals throughout the day (taken with thermocouples and a Leeds and Northrup potentiometer).

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[1]Contribution No. 733 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

## Results and Discussion

Yield records for the last three seasons are presented in Table I. Sawdust-mulched plots produced significantly higher yields every year, while clean-cultivated plots consistently produced the lowest yield. Differences in yield between other treatments were not consistent. In 1946, straw-mulched plots yielded significantly higher than those under clean cultivation; in 1947 all treatments were significantly better than clean cultivation and in 1948 clean cultivation plus cover crop was significantly better than clean cultivation alone.

TABLE I—Yield of Pioneer Blueberries Under Various Soil Management Treatments*

| Treatment | Yield in Quarts Per Acre | | |
|---|---|---|---|
| | 1946 | 1947 | 1948 |
| Sawdust mulch | 3,528 | 3,301 | 3,144 |
| Straw mulch | 1,849 | 2,294 | 2,296 |
| Clean cultivation and cover crop | 1,634 | 2,665 | 2,647 |
| Clean cultivation | 1,405 | 1,646 | 2,113 |

*Differences required for significance at 99:1 odds are 349.54 for 1946, 594.12 for 1947, and 428.9 or 1948.

Data on soil pH under different treatments are presented in Table II.

TABLE II—Soil pH as Affected by Soil Management*

| Treatment | pH 0 to 6 Inches | pH† 6 to 12 inches | Average |
|---|---|---|---|
| *1947* | | | |
| Sawdust mulch | 4.4 | 4.5 | 4.5 |
| Straw mulch | 4.3 | 4.3 | 4.3 |
| Clean cultivation and cover crop | 4.1 | 4.3 | 4.2 |
| Clean cultivation | 4.0 | 4.1 | 4.0 |
| *1948* | | | |
| Sawdust mulch | 4.6 | 4.5 | 4.5 |
| Straw mulch | 4.7 | 4.5 | 4.6 |
| Clean cultivation and cover crop | 4.4 | 4.3 | 4.3 |
| Clean cultivation | 4.3 | 4.2 | 4.3 |

*Each reading represents an average of 5 samples, one from each replicate. All averages are based on H-ion concentrations.
†pH determinations were made by the Agricultural Chemistry Department.

Differences in the soil pH under various treatments were very small but fairly consistent. The highest pH was under mulches and the lowest in clean cultivated plots. Even though the differences were very small they were quite consistent indicating that both mulches tended to raise rather than lower soil pH. Griggs (3), working at Connecticut with a similar experiment, has found that in 5 years the soil reaction under clean cultivation was lowered from pH 5.7 to 4.9, while under sawdust it decreased only 0.4 pH, from pH 5.9 to 5.5.

Only limited numbers of soil moisture determinations were made. The moisture content varied during the season but data in Table III indicate the predominant relationship under the different treatments.

TABLE III—SOIL MOISTURE AS AFFECTED BY SOIL MANAGEMENT

| Treatment | Soil Moisture (Per Cent) |
|---|---|
| Straw mulch | 35 |
| Sawdust mulch | 29 |
| Clean cultivation | 21 |

Soil moisture was usually highest under the straw mulch, less under sawdust-mulched plots and lowest under clean-cultivated plots. In order to obtain a more complete picture of moisture conditions under different treatments throughout the season, frequent moisture determination are planned for the next year.

It was impossible to obtain continuous soil temperature records under different cultural treatments simultaneously, but three representative charts are shown illustrating normal trends (Figs. 1 to 3).

Fig. 1 shows soil temperatures plotted at 2-hour intervals under the straw mulch. Temperature fluctuation for these 6 days did not exceed 5 degrees F and the temperature changes were very gradual.

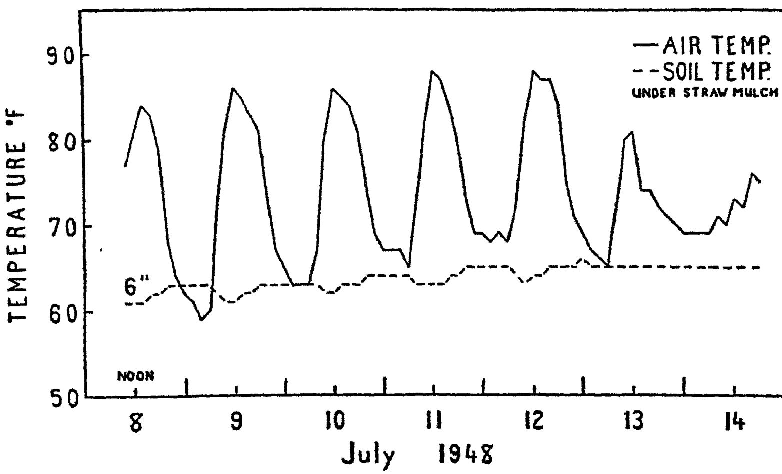


FIG. 1. Soil temperature under the straw mulch.

Fig. 2 shows soil temperature conditions under the sawdust mulch. Both charts are very similar except that temperature under the sawdust mulch was slightly higher. They also illustrate the fact that changes in air temperature do not easily influence the soil temperature under mulches. During some nights air temperature was down to 50 degrees F, while during other nights it was as high as 68 degrees F, although the general trend of soil temperature remained the same.

Differences in moisture and temperature under the two mulches may be partially due to the thickness and color of the mulch. Straw mulch was about 4 inches thick and lighter than sawdust in color, while sawdust mulch was about 3 inches thick and darker in color, thus absorbing more heat.

Under both mulches the high point in soil temperature roughly coincided with the low point of air temperature; therefore, in general, soil temperature lagged about 12 hours behind those of air temperatures.

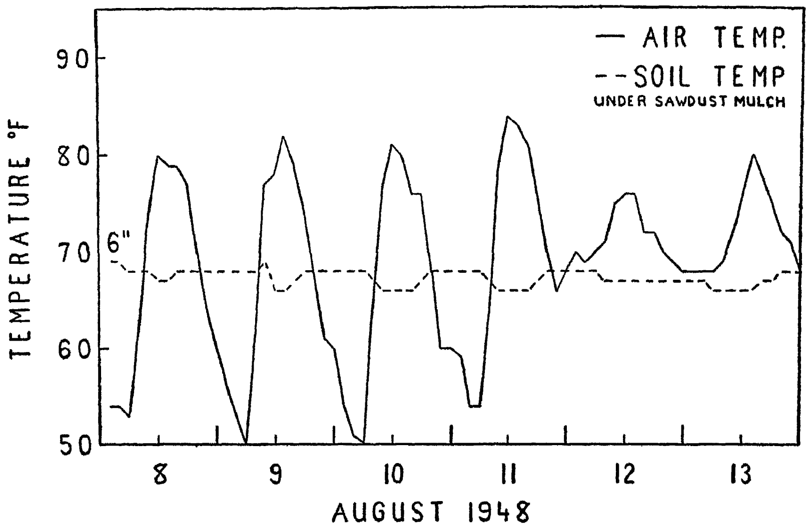


FIG. 2. Soil temperature under the sawdust mulch.

Fluctuations of soil temperature under clean cultivation (Fig. 3) were very great and often soil temperature approximated air temperature. There was a lag of about 4 hours between the air and the soil temperatures.

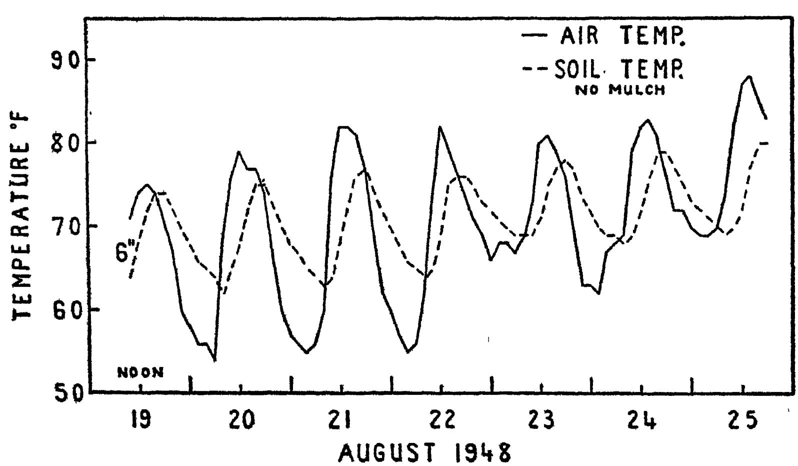


FIG. 3. Soil temperature — clean cultivation.

Because the above soil temperature records were not obtained at the same time, some additional readings were taken with thermocouples to compare soil temperature under the same conditions of moisture, light, air temperature, and so on. Fig. 4 shows temperature records on two different days. The data substantiate the statement previously made that there is great variation under clean cultivation and very little fluctuation under the mulches. It also shows that soil under the straw was slightly cooler than that under the sawdust.

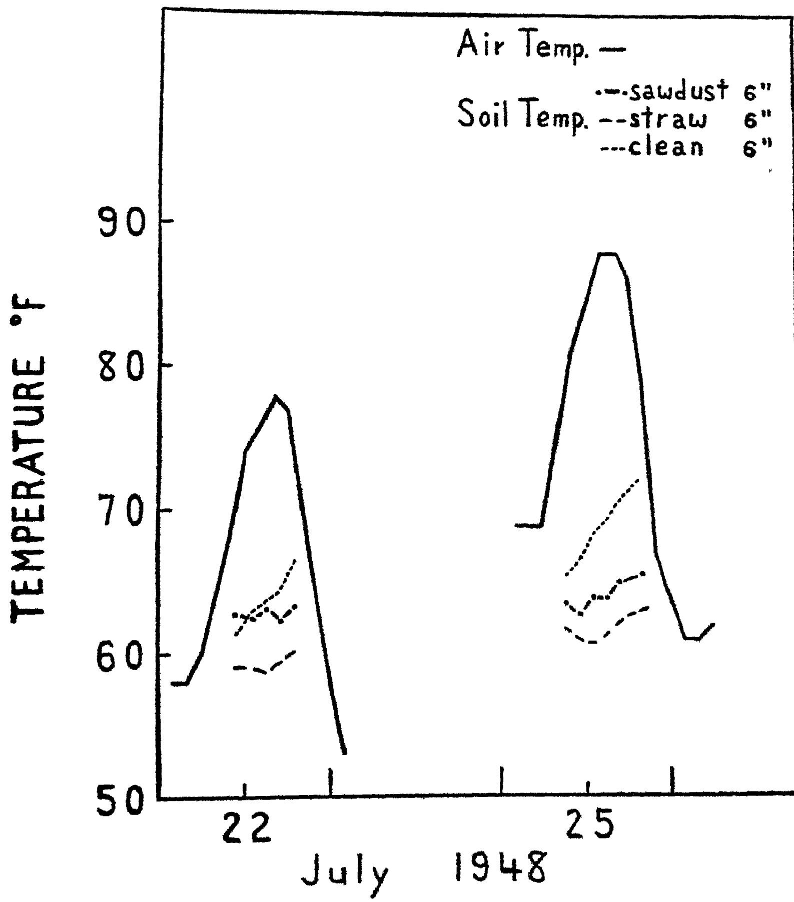


FIG. 4. Soil temperature under clean cultivation, straw mulch and sawdust mulch.

It should be mentioned that bushes in the sawdust plots developed numerous fibrous roots extending into the sawdust. These roots probably increased the nutrient and water-absorbing capacity of the bushes, which may account in part for the higher yields from this treatment.

## Conclusions

1. Sawdust-mulched plots produced significantly higher yields than plots under straw mulch, clean cultivation plus cover crop or clean cultivation throughout.

2. Soil pH was significantly higher under the sawdust mulch than in clean-cultivated plots.

3. Soil moisture was greatest under straw mulch, less under sawdust, and least under clean cultivation.

4. Soil temperature of plots under mulches showed very little fluctuation; changes lagged about 12 hours behind those of the air temperature. Soil temperature in clean-cultivated plots exhibited great fluctuation, often approximating air temperature with a lag of about 4 hours for the change.

## Literature Cited

1. Chandler, F. B., and Mason, J. C. Effect of mulch on soil moisture, soil temperature and growth of blueberry plants. *Proc. Amer. Soc. Hort. Sci.* 40: 335–337. 1942.
2. Christopher, E. P., and Shutak, V. G. Influence of several soil management practices upon the yield of cultivated blueberries. *Proc. Amer. Soc. Hort. Sci.* 46: 211–212. 1947.
3. Griggs, W. H., and Rollins, H. A. Effect of planting treatment and soil management system on the production of cultivated blueberries. *Proc. Amer. Soc. Hort. Sci.* 49: 213–218. 1947.
4. Kramer, Amihud, Evinger, E. L., and Schrader, A. L. Effect of mulches and fertilizers on yield and survival of dryland and highland blueberries. *Proc. Amer. Soc. Hort. Sci.* 38: 455–461. 1941.
5. Savage, E. F., and Darrow, G. M. Response of blueberries under clean cultivation and various kinds of mulch materials. *Proc. Amer. Soc. Hort. Sci.* 40: 338–340. 1942.

# The Efficacy of Cane and Trunk Ringing of Grapevines[1]

By A. S. Dhillon, *Michigan State College, East Lansing, Mich.,* and Lal Singh, *Department of Agriculture, East Punjab, India*

The practice of ringing is an old established one, especially in viticulture. Fuller (2) ascribed its introduction to a French viticulturist named Col. Buchatt about 1745. It was claimed by him that the practice would be of great value in hastening the maturity as well as in improving the quality of grapes. Perold (4) expressed a similar opinion and stated that ringing might be of value for producing high class table grapes. As reported in another paper (1), cane ringing hastened the maturity appreciably and also increased the size of berries and total yield of fruit. The experiment here reported was set up to compare the effects of cane and trunk ringing in the experimental orchard of the Punjab Agricultural College and Research Institute, Lyallpur, India.

## Materials and Methods

The experiment included three treatments: 1, cane ringing; 2, trunk ringing; and 3, cane plus trunk ringing.

Eighteen vines of the Black Prince variety of grape (*Vitis vinifera*) were selected on the basis of girth records, in the winter of 1943. They were grouped into three lots of six vines each for experimental treatments. They were pruned to a cane system leaving 10 canes of 10 buds each and with an equal number of renewal spurs per vine. The experimental treatments were given a week after fruit set, in the last week of April, as follows:

1. *Cane Ringing:*—Complete rings of bark from $^1/_6$ to $^1/_4$ inch wide were removed from the bases of 1-year-old canes leaving the first two or three basal shoots which bore no fruit.
2. *Trunk Ringing:*—Trunks were ringed 9 inches above the soil level. The width of rings was the same as in the case of cane ringing ($^1/_6$ to $^1/_4$ inch).
3. *Cane Plus Trunk Ringing:*—Canes as well as trunks were ringed.

The cane girdles healed, apparently, 4 weeks after treatment while the trunk girdles required at least another week before healing. The healed regions were not reopened. The analytical methods followed were the same as discussed in another paper (1).

## Presentation of Data and Discussion

*Time of Ripening of Fruit:*—The data in Table I show that cane plus trunk ringing was more effective in maturing greater quantities

[1]A part of the thesis presented by the senior author to the University of Punjab, India, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

The authors wish to express their appreciation to Dr. A. A. Khan and Dr. Sham Singh, Department of Agriculture, Punjab, for suggestions during the course of these investigations and to Dr. H. B. Tukey and Dr. J. E. Moulton, Michigan State College, for help in the preparation of the manuscript.

TABLE I—CUMULATIVE PERCENTAGE OF CROP RIPENED (1943)

| Treatment | June | | | | | July | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 14 | 19 | 24 | 29 | 6 | 12 | 14 |
| Cane ringing | 1.6 | 6.8 | 10.6 | 13.7 | 23.7 | 71.0 | 97.7 | 100.0 |
| Trunk ringing | 0.8 | 6.1 | 6 3 | 12.3 | 28.0 | 88.5 | 88.5 | 100.0 |
| Cane + trunk ringing | 1.6 | 16.3 | 25.2 | 37.6 | 46.3 | 82.2 | 100.0 | — |

of crop earlier than either of the treatments used singly. By June 19, 1943, approximately 25 per cent, 11 per cent, and 6 per cent of the total crop was picked from cane plus trunk ringed, cane ringed and trunk ringed vines, respectively. By double girdling, most of the elaborated foods may have been held above the girdles on the canes and made available to the rapidly developing fruit in the earlier stages when the cane girdles were effective, whereas in the later stages when the cane girdles healed completely, the trunk girdles were still effective and the developing fruit could utilize a part of the accumulated food which was not allowed to pass down to the roots. These conditions, in the case of cane plus trunk-ringed vines, may have resulted in providing more food to the fruit to enable it to mature and ripen earlier.

In addition to this, it is interesting to note that in one of the late pickings on July 6, as much as 61 per cent was harvested from trunk ringed vines, whereas on the same date 47 per cent and 36 per cent of the crop was picked from the cane ringed and trunk plus cane ringed vines, respectively. This shows that trunk ringing did not influence early maturity of fruit to the same extent as did the remaining two treatments for the possible reason that the carbohydrates manufactured by the leaves were as much at the disposal of the non-bearing shoots and the trunks above the girdles as the bearing shoots, with the consequent result that a greater quantity of fruit ripened later in the season. It may also be concluded that trunk ringing affects the vines more uniformly since greater quantity of the fruit ripened at one time. Jacob (3) has mentioned that "trunk girdling is favored over girdling the arms or fruit canes because it affects the whole vine uniformly". He has also stated that trunk girdling is the cheapest. However, Perold (4) has advised not to girdle the trunks as it weakens the vine.

*Total Yield and Size of Berries:*—The data presented in Table II demonstrate that there was no significant difference in yield or berry size due to different methods of ringing followed. These results clearly point out that girdling may be done either on trunks or on canes with almost equally good results with regard to yield and size of berries.

TABLE II—TOTAL YIELD AND SIZE OF BERRIES (1943)

| | Cane Ringing | Trunk Ringing | Cane Plus Trunk Ringing |
|---|---|---|---|
| Yield per vine (pounds) | 13.76 | 13.90 | 13.35 |
| Weight per berry (grams) | 3.01 | 2.98 | 2.89 |

*Quality of Fruit:*—The data regarding the juice-pomace ratio, acidity and sugar contents and sugar-acid ratio of fruit picked on July 6 (Table III) do not reveal any significant differences among the treatments. On July 6 the maximum amount of crop was picked under each treatment considering any single harvest, and hence this date was selected for comparison of fruit quality.

TABLE III—QUALITY OF FRUIT (JULY 6, 1943)

| | Cane Ringing | Trunk Ringing | Cane Plus Trunk Ringing |
|---|---|---|---|
| Juice-pomace ratio | 5.92 | 5.65 | 5.65 |
| Percentage of acidity | 0.58 | 0.55 | 0.59 |
| Percentage of sugars | 17.37 | 17.30 | 17.51 |
| Sugar-acid ratio | 30.25 | 32.09 | 30.09 |

*Vigor of Grapevines:*—The data on the weight of prunings and the increase in cross-sectional area of trunks are shown in Table IV.

The greater increase in cross-sectional area of trunk-ringed vines may be explained by the fact that the trunks above the girdles in this case could grow better as compared with trunks of cane-ringed or cane plus trunk-ringed vines and since the measurements of trunks were made above the trunk girdles, a higher figure might be expected for trunk-ringed vines. However, a statistical analysis of the results revealed these differences to be non-significant. The weight of prunings also did not depict any appreciable differences. It may be said that the vigor of vines under the three methods of ringing at the end of the first year's treatment was more or less alike.

TABLE IV—VIGOR OF GRAPEVINES (1944)

| | Cane Ringing | Trunk Ringing | Cane Plus Trunk Ringing |
|---|---|---|---|
| Total weight of 1-year-old wood removed (ounces) in pruning after one year of the application of treatments | 32.60 | 27.30 | 29.70 |
| Increase in cross-sectional area of trunks (sq cms) | 2.01 | 3.52 | 2.88 |

## SUMMARY AND CONCLUSIONS

Results regarding the efficacy of different methods of ringing are reported.

Cane plus trunk ringing proved more effective in hastening maturity than cane or trunk ringing alone.

The vines under the different methods of ringing behaved alike in yield and size of berries, showing thereby that each method can be practiced with equally good results.

No differences with regard to sugar and acid contents were found in fruit under the three methods of ringing employed.

The vigor of grapevines did not differ appreciably in favor of any of the methods of ringing tested.

It may be concluded that any one method of ringing tested can be

practiced with equally good results insofar as total yield and quality of fruit are concerned. However, ringing of both canes and trunks to get a greater quantity of fruit early in the season may not be desirable. Trunk ringing, although seemingly less expensive, is not advisable because the experience of others indicates it may eventually weaken the vines. Ringing is preferably done on canes or those parts which are to be removed in the following season.

## Literature Cited

1. Dhillon, A. S., and Singh, Lal. The influence of thinning and ringing on the cropping and quality of grapes and the vigor of grapevines. *Proc. Amer. Soc. Hort. Sci.* 1949.
2. Fuller, A. S. *The Grape Culturist.* Orange Judd Co., New York. 1911.
3. Jacob, H. E. Grape growing in California. *Calif. Cir.* 116. 1940.
4. Perold, A. I. *A Treatise on Viticulture.* MacMillan & Co., Ltd., London. 1927.

# The Influence of Thinning and Ringing on the Cropping and Quality of Grapes and the Vigor of Grapevines[1]

By A. S. DHILLON, *Michigan State College, East Lansing, Mich.*, and LAL SINGH, *Department of Agriculture, East Punjab, India*

UNDER a given set of conditions, various cultural practices like pruning, thinning, and ringing are known to play an important part in improving the quality of fruit. The purpose of the investigations here reported was to study the influence of thinning and ringing separately and in combination on the cropping and quality of grapes and the vigor of grapevines, under the climatic conditions of the Punjab, a north-western province of India.

## MATERIALS AND METHODS

The experiment consisted of four treatments: 1, control; 2, fruit thinning; 3, cane ringing; and 4, fruit thinning plus cane ringing.

Twenty-four own-rooted vines of the Black Prince variety of grape (*Vitis vinifera*) were selected in the winter of 1943, in the experimental orchard of the Punjab Agricultural College and Research Institute, Lyallpur, India. The vines were 6 to 7 years old, moderately vigorous, and growing in heavy loam soil in rows set 15 feet apart and with 7½ feet between plants.

In the second week of February, 1943, all the vines were pruned to a cane system leaving 10 canes of 10 buds each and with an equal number of renewal spurs, per vine. The 1-year-old wood removed in pruning was weighed separately for each vine to serve as an index of vigor. However, the main criterion of vigor used was trunk girth which was measured at a marked height of 1 foot from the soil level. Six vines were allotted to each treatment, distributing the variability uniformly with regard to vigor among all the treatments. The experimental treatments were given during the fourth week of April, about a week after the fruit had set, as follows:

1. *Control:*—No treatment.
2. *Fruit Thinning:*— The shoulders and tips of the clusters were removed, leaving 8 to 10 floral branches on each cluster.
3. *Cane Ringing:*—Complete rings of bark from $^1/_8$ to $^1/_4$ inch wide were removed from the bases of 1-year-old canes leaving the first two or three basal shoots which were usually very small and bore no fruit.
4. *Fruit Thinning Plus Cane Ringing:*—The vines were thinned like those under No. 2 and ringed like those under No. 3.

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[1]A part of the thesis presented by the senior author to the University of Punjab, India, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

The authors wish to express their appreciation to Dr. A. A. Khan and Dr. Sham Singh, Department of Agriculture, Punjab, for suggestions during the course of these investigations and to Dr. H. B. Tukey and Dr. J. E. Moulton, Michigan State College, for help in the preparation of the manuscript.

In many cases, the girdled regions healed, apparently, 4 weeks after the treatment, and at this time the wounds were reopened. Finally, the girdles again started healing 3 weeks after reopening and they were allowed to heal.

The fruit from the experimental vines was picked at varying intervals as it attained the color characteristic of the variety. The weight of the ripe crop was recorded separately for each vine at each harvest and the percentage of ripe crop calculated.

At the peak of the harvest season, 100 berries from representative bunches selected from each vine were weighed in order to determine the comparative size of the berries under the different treatments.

From each harvest, samples of fruit were analyzed for such quality factors as juice-pomace ratio, total soluble solids, acidity and sugars.

In determining the ratio of juice to pomace, the berries were weighed and the juice squeezed through a two-fold muslin cloth by using uniform pressure. The weight of the pomace left in the cloth was subtracted from the original weight of the berries to obtain the weight of the juice.

The total soluble solids were determined by the use of the refractometer. The values for total soluble solids showed close correlation with the amount of sugars estimated by the volumetric method developed by Lane and Eynon (6) and hence no separate data are presented on total soluble solids. In the volumetric method adopted, the amount of sugars per 100 cc of original juice was calculated.

Acidity was calculated in terms of tartaric acid by titrating the juice against standard sodium hydroxide solution.

In order to study the after-effect of different treatments on the growth of vines, girth measurements were made in January 1944, at a height of 1 foot marked and measured the previous year. The weight of 1-year-old wood removed in pruning in February 1944, and the total measurement of shoot growth were also recorded.

## Presentation of Data and Discussion

*Time of Ripening of Fruit:*—An appreciable quantity of fruit from control vines was picked on June 21 for the first time (Table I). Using the control vines as a basis for comparison, the dates of first picking show that the maturity of fruit was hastened by 4 days in the case of the thinning treatment and 14 days in the case of the other two treatments.

TABLE I—Cumulative Percentage of Crop Ripened (1943)

| Treatment | June | | | | | | July | |
|---|---|---|---|---|---|---|---|---|
| | | | | 17 | 21 | 26 | 2 | 8 |
| Control | | | | 0.3 | 3.9 | 47.6 | 82.9 | 100.0 |
| Thinning | | | | 7.6 | 29.6 | 76.7 | 95.0 | 100.0 |
| | June | | | | | | July | |
| | 7 | 10 | 15 | 18 | 23 | 28 | 5 | 10 |
| Ringing | 3.5 | 10.8 | 42.5 | 48.5 | 60.5 | 69.2 | 79.8 | 100.0 |
| Thinning + ringing | 19.7 | 38.8 | 65.7 | 69.4 | 85.7 | 89.7 | 95.6 | 100.0 |

By June 17 approximately 0 and 8 per cent of the fruit was picked from control and thinned vines respectively, whereas by about the same date (June 18) the percentage of ripened crop picked from vines under ringing and thinning plus ringing treatments was approximately 49 and 69 per cent respectively. Thus about one-half the total crop from ringed vines and two-thirds the total crop from the vines thinned and ringed was harvested before the ripening of fruit started on the untreated vines. Another interesting point brought out by the figures is that ringing extended the ripening period of the fruit.

The thinned vines carried more leaf area per unit weight of fruit which probably was responsible for early maturity. The hastening of maturity by thinning has been reported by many workers such as Winkler (12) and Ragland (10).

Most of the evidence suggests that the early maturity of fruit under ringing treatment was a direct result of the increased availability of elaborated food materials in the parts above the ring. Hastening of maturity due to ringing has been reported by Murneek (8), Bonnet (2) and many others. However, Jacob (4) working on Hunisa grape did not observe any earliness of maturity due to ringing.

Thinning combined with ringing was the most effective treatment in bringing about the early maturity of fruit. This may be explained by the fact that high leaf-fruit ratio resulting from fruit thinning in addition to the check of the downward passage of elaborated food materials manufactured in the leaves resulting from the ringing provided conditions favorable for the maturation of fruit early in the season.

*Total Yield and Size of Berries:*—The total yield of thinned vines was reduced as compared with the control because the reduction in the number of berries per cluster resulting from thinning was not compensated for by the slight increase in berry size (Table II). These results are in agreement with those obtained by Winkler (12) and Partridge (9).

TABLE II—TOTAL YIELD AND SIZE OF BERRIES (1943)

| | Control | Thinning | Ringing | Thinning Plus Ringing | L.S.D. at 5 Per Cent Level |
|---|---|---|---|---|---|
| Yield per vine (pounds) | 10.76 | 8.90 | 12.88 | 10.84 | 1.71 |
| Weight per berry (grams) | 2.61 | 2.80 | 3.25 | 3.27 | 0.23 |

The increase in yield due to ringing can be accounted for by the increase in berry size. These results corroborate the findings of Jacob (5). The yield was not affected when the vines were both thinned and ringed. Apparently, the improvement in the size of berries was sufficient to make up the loss in yield resulting from thinning.

*Quality of Fruit as Judged by Juice-Pomace Ratio, Acidity, Sugars and Sugar-acid Ratio:*—The analyses of juice of fruit under various treatments were made on different dates as the fruit matured. However, the fruit harvested on June 26 from the control and thinning treatments has been compared with fruit picked on June 23 from the ringing and thinning plus ringing treatments. The results are presented

in Table III. As far as juice-pomace ratio is concerned no significant differences were noticed among treatments. The data on the acid content reveal that the percentage of acidity was unaffected by thinning, but the acid level was significantly higher where the canes had been ringed. The acid content was greater, but not significantly so, in the berries from vines both thinned and ringed.

TABLE III—QUALITY OF FRUIT (1943)

| | June 26 | | June 23 | | L.S.D. at 5 Per Cent Level |
|---|---|---|---|---|---|
| | Control | Thinning | Ringing | Thinning Plus Ringing | |
| Juice-pomace ratio | 4.33 | 4.73 | 4.94 | 4.78 | — |
| Percentage of acidity | 0.67 | 0.67 | 0.84 | 0.75 | 0.12 |
| Percentage of sugars | 14.52 | 14.94 | 12.01 | 12.11 | 1.82 |
| Sugar-acid ratio | 22.12 | 22.68 | 14.52 | 16.22 | 3.65 |

The sugar percentages of fruit under ringing and thinning plus ringing treatments were lower than those of fruit under control and thinning. The differences between the thinned and control vines on one hand and those between the ringed and thinned plus ringed vines on the other were not significant. Irrespective of treatments it was observed that the sugar concentration increased with every harvest whereas the acidity decreased. However, the fruit from ringed and thinned plus ringed vines never compared favorably with the fruit from control and thinned vines. It seems ringing allowed the berries to develop color and assume the appearance of ripeness earlier, but actually they were not ripe. So it is suggested that in order to improve the sugar-acid ratio, the fruit be retained on the ringed vines for a longer period, even if it attains the color characteristic of the variety.

The fruit picked on June 23, from ringed and thinned plus ringed vines had low sugar-acid ratio as compared with the fruit harvested later on June 26, from control and thinned vines. These results confirm those of Husmann (3). Murneek (8) and Bonnet (2) obtained diametrically opposite results from those reported here. The work of Bonnet shows that he compared grapes picked on the same date from girdled and ungirdled shoots when the fruit on the girdled branches was fully ripe, whereas the fruit from ungirdled ones had not completely matured, and thus he could obtain higher sugar and lower acidity in girdled as compared with ungirdled bunches. Other workers may also have made the comparison in this way.

In the case of fruit from control and thinning treatments, no differences were noticed with regard to acidity and sugars as well as sugar-acid ratio, whereas Winkler (12) and Moon (7) found that thinning increased the sugar-acid ratio. It is probable that these workers allowed the fruit on the thinned vines to hang till such time as the fruit on the unthinned vines also matured for the purposes of comparison. As the fruit on thinned vines generally begins to ripen earlier, it must have been in a more advanced stage of maturity as compared to that on unthinned vines.

The insignificant increase in berry size and no improvement in sugar-acid ratio following thinning may be explained in terms of increased trunk and shoot growth (Table IV). Aldrich (1) also did not find any increase in carbohydrate content of pear fruit resulting from thinning and suggested that thinning results in increased limb and shoot enlargement and consequently less of the food manufactured by the leaves is left for utilization by the fruit.

*Vigor of Grapevines as Judged by Total Weight of Prunings, Total Extension Growth, Weight of 1-Year-Old Wood Per Unit Length and the Increase in Cross-Sectional Area:*—The data are presented in Table IV. The total weight of 1-year-old wood removed in pruning following the thinning treatment was greater than that removed after any of the other three treatments. As far as total extension growth at the end of the growing season is concerned, the differences under various treatments were insignificant. The weight per meter

TABLE IV—VIGOR OF GRAPEVINES (1944)

| | Control | Thinning | Ringing | Thinning Plus Ringing | L.S.D. at 5 Per Cent Level |
|---|---|---|---|---|---|
| Total weight of 1-year-old wood (grams) removed in pruning (1944) | 1019 | 1641 | 1028 | 1130 | 394 |
| Total extension growth (meters) | 57.43 | 70.43 | 58.92 | 63.62 | 16.06 |
| Weight of 1-year-old wood (grams) per meter | 17.10 | 23.30 | 17.50 | 17.50 | 2.96 |
| Increase in cross-sectional area of trunks (sq cms) | 3.92 | 5.40 | 2.49 | 2.81 | 2.18 |

of growth was greater in the case of thinned vines than for any of the remaining three treatments. The data on the increase in cross-sectional area show that the vines under the thinning treatment made more growth in stem thickness than those under the ringing and the thinning plus ringing treatments. The difference between the control and thinned vines, however, was not significant.

The results emerging from the present investigations are sufficiently conclusive to indicate that thinning was associated with increased vigor of the vines when compared with other treatments. The weakening effect of girdling when compared with thinning, was also quite evident. However, the difference between the girdled and control vines was not appreciable during the first year of the treatment, at least. Shamel and Pomeroy (11) did not find any measurable effect on the growth of stem of Washington Navel orange for the first few girdlings but depressed growth became apparent after seven or eight girdlings.

## SUMMARY AND CONCLUSIONS

Thinning of fruit, ringing of canes and a combination of these practices hastened the maturity of fruit of the Black Prince grape.

Thinning reduced the yield because the insignificant improvement in berry size did not make up the loss in number of berries which resulted from thinning. The yield was increased by ringing which was the direct result of increase in berry size.

The fruits from ringed and thinned plus ringed vines had lower sugar-acid ratio than the fruits from control and thinned vines under the conditions of the experiment.

The effects of different treatments on the vigor of vines were noticeable even at the end of the first year of the treatments. Thinning seemed to invigorate the vines as compared to other treatments.

In conclusion, it may be said that thinning may be practicable when the vines have a tendency to overbear and become devitalized, but ringing may be practicable where vines are vigorous and where early fruit is in great demand without regard to high quality (in terms of high sugar-acid ratio). A combination of both these practices may be adopted where the vines are of moderate vigor and where early fruit is desired.

### Literature Cited

1. Aldrich, W. W. Pear fruit thinning in relation to yield and size of fruit for the same reason. *Proc. Amer. Soc. Hort. Sci.* 30: 332–340. 1933.
2. Bonnet, L. O. New facts about girdling. *Calif. Grape Grower* 6: 2. 1925.
3. Husmann, G. C. Currant-grape growing: A promising new industry. *U.S.D.A. Bul.* 856. 1920.
4. Jacob, H. E. The response of the Hunisa grape to girdling. *Proc. Amer. Soc. Hort. Sci.* 32: 386–388. 1934.
5. ———— Grape growing in California. *Calif. Cir.* 116. 1940.
6. Lane, J. H., and Eynon, L. Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *Jour. Soc. Chem. Ind. Trans.* 42: 32–37. 1923.
7. Moon, H. H., *et al.* The effect of load of fruit on the tree upon composition. flavor, and dessert, and canning quality of twelve varieties of peaches. *Fruit Products Jour.* 21: 46–50, 54, 61. 1941.
8. Murneek, A. E. Fruit production as affected by branch ringing. *Proc. Amer. Soc. Hort. Sci.* 37: 97–100. 1939.
9. Partridge, N. L. The influence of long pruning and thinning upon the quality of Concord grapes. *Proc. Amer. Soc. Hort. Sci.* 28: 144–146. 1931.
10. Ragland, C. H. A preliminary report on the effect of cluster thinning on the maturity, yield, and cluster size of grapes. *Proc. Amer. Soc. Hort. Sci.* 37: 661–662. 1939.
11. Shamel, A. D. and Pomeroy, C. S. Report on a girdling test with Washington Navel orange tree. *Calif. Citro.* 21: 320. 343. 1936.
12. Winkler, A. J. Berry thinning of grapes. *Calif. Exp. Sta. Bul.* 492. 1930.

# Parents Useful in Breeding Autumn-Fruiting Red Raspberries For Virginia

By George D. Oberle, R. C. Moore and J. O. Nicholson,
*Virginia Agricultural Experiment Station, Blacksburg, Va.*

The fruit breeding program of the Virginia Agricultural Experiment Station includes a project on raspberry breeding. At present Latham, Indian Summer, and Sunrise are the only red varieties that have shown sufficient promise under tests at Blacksburg to warrant recommendation for planting in Virginia. Each of these varieties has serious shortcomings as grown at Blacksburg. Because they are better adapted to Virginia conditions than other varieties under test, however, they seemed to offer promise as the basis for a program of raspberry breeding designed to develop types adapted particularly to Virginia.

The development of fall-fruiting types has been discussed historically by Slate (3). He reported that Lloyd George and its seedlings were the best source yet discovered of the autumn-fruiting character and was of the opinion that interbreeding of such material should offer a relatively rapid means of developing autumn-fruiting types for New York. Later Slate and Suit (5) concluded that such interbreeding of the Lloyd George descended material resulted in too great a degree of inbreeding with a corresponding loss of vigor and greater susceptibility to diseases. They suggested outcrossing of such material with somewhat unrelated material. Slate in a third report (5) reports good results from crossing some of the Lloyd George descended selections with early ripening autumn-fruiting selections of *Rubus strigosus* collected in Oswego County, New York. Waldo and Darrow (6) also reported that Lloyd George was the best parent for breeding fall fruiting types in Washington. For Maryland conditions crossing Lloyd George with Ranere produced promising seedlings. Drain (2) crossed a Latham x Van Fleet seedling with Lloyd George to produce the Tennessee Autumn variety.

Lloyd George is so poorly adapted to Virginia conditions that maintaining it at Blacksburg for use in breeding has been impossible. Ranere, too, performs poorly and is much inferior in performance to its seedling, Sunrise, and to Indian Summer. In 1946, Quentin Zielinski and J. O. Nicholson made crosses using Sunrise, Indian Summer and other varieties of red raspberries as parents. The seed was germinated in the greenhouse in 1947 and the seedlings were set in a fruiting planting later in the spring. A moisture deficiency in the summer of 1947 restricted the growth of the seedlings to some extent. As a result only a light summer crop of fruit was borne in 1948. Favorable growing conditions occurred in 1948, however, and as the summer progressed it became evident that many plants would bear an autumn or late summer crop. Records were taken on the occurrence of autumn fruiting types and dates of ripening and the data presented in Table I were compiled from those records.

The Indian Summer x Sunrise, Indian Summer x Latham, Taylor

x Sunrise and Sunrise x Newburgh populations include seedlings of reciprocal crosses. The seedlings of reciprocal crosses were grouped because only in the case of the Latham x Indian Summer and the Indian Summer x Latham crosses was there an appreciable difference in the population of fall fruiting individuals obtained. The percentage of autumn-fruiting types was calculated on the basis of surviving seedlings. These calculations should not be interpreted too literally for as Slate (3) and Waldo and Darrow (6) have emphasized, the autumn-fruiting character is a difficult one to classify and its expression is much influenced by environment. Strong plants develop their autumn crop earlier and more abundantly than weak plants. Some of the plants included in this study were so lacking in vigor that they probably were unable to exhibit the autumn-fruiting habit even though they may carry the genetic factors for that character. The data on season of ripening were compiled on the following basis. Seedlings given an autumn crop ripening date in August were classed as early. Those having ripening dates in September were classed as midseason and those not ripe on October 1, were placed in the late season group. The latter included individuals varying in development of fruit from seedlings with nearly ripe berries to seedlings with very small blossom buds.

The data in Table I show that Indian Summer and Sunrise both transmit the autumn-fruiting habit. Slate (3, 4) has reported on the

TABLE I—SEGREGATION OF THE AUTUMN-FRUITING CHARACTER AND SEASON OF RIPENING OF THE AUTUMN CROP IN RED RASPBERRY SEEDLINGS

| Parentage | Original Population Planted | Seedlings Surviving | Seedlings With Autumn-Fruiting Habit | | Ripening Season of Autumn-Fruiting Types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Early | | Mid-Fall | | Late | |
| | | | No. | Per Cent | No. | Per Cent | No. | Per Cent | No. | Per Cent |
| Indian Summer × Sunrise | 579 | 406 | 96 | 23.6 | 47 | 11.4 | 45 | 11.0 | 4 | 1.0 |
| Indian Summer × Latham | 361 | 282 | 18 | 6.3 | 1 | 0.3 | 5 | 1.7 | 12 | 4.2 |
| Taylor × Sunrise | 179 | 165 | 35 | 21.1 | 7 | 4.2 | 11 | 6.7 | 17 | 10.3 |
| Sunrise × Newburgh | 46 | 39 | 2 | 5.1 | 1 | 2.5 | 1 | 2.5 | — | — |
| Sunrise × Marcy | 21 | 18 | 4 | 22.2 | 2 | 9.1 | 2 | 9.1 | — | — |
| Sunrise selfed | 16 | 11 | 0 | — | — | — | — | — | — | — |

value of Indian Summer as a parent in breeding for the autumn-fruiting character. No reference appears to have been published concerning the ability of Sunrise to transmit that character. Sunrise is, of course, a summer fruiting variety although Darrow and Clark (1) report that the variety occasionally produces a few berries in the fall in New Jersey but not enough to be of commercial interest. At Blacksburg in September of 1948, one shoot of Sunrise was observed to bear fruit in a 25-foot section of row. Sunrise is a seedling of Ranere and hence may well carry a factor or factors for autumn-fruiting without displaying it. Indian Summer crossed with Latham produced only 6.3 per cent of autumn-fruiting seedlings as compared to 23.6 per cent when crossed with Sunrise. Sunrise, when crossed with Taylor and Marcy produced 21.1 and 22.2 per cent of autumn-fruiting seedlings. Like

Indian Summer, Taylor and Marcy are seedlings of Lloyd George. Though they seldom produce berries in the fall, they may carry a factor for autumn-fruiting. This view appears to be supported by the fact that Sunrise crossed with Newburgh produced only 5.1 per cent of seedlings with the autumn-fruiting character. A population of self-pollinated Sunrise seedlings did not include any autumn-fruiting individuals, but only 11 seedlings of this parentage were included in the study and these were of low vigor as self-pollinated seedlings of red raspberry usually are. It is the opinion of the authors that Sunrise carries a factor or factors for autumn-fruiting derived from its Ranere parent, which differs from those possessed by Indian Summer and other varieties of Lloyd George ancestry. When Sunrise is crossed with varieties having the Lloyd George factors for autumn-fruiting these two groups of factors appear to interact in a complementary fashion to produce a higher proportion of autumn-fruiting seedlings than is produced when either the Lloyd George or the Ranere factors are hybridized with varieties possessing neither of these factors. The mode of inheritance of the autumn-fruiting character has been described as being complex by Slate (3, 4) and by Waldo and Darrow (6). Our data appears to support that opinion. In view of the limited populations available for study, the mortality of plants occurring under Virginia conditions and the lack of vigor exhibited by many seedlings in the planting at Blacksburg, it appears unwise to attempt a genetic analysis of this character.

Another interesting feature of the Sunrise populations was the high proportions of seedlings ripening during August. Though early ripening of the fall crop is less essential in Virginia than in more northerly areas it is none-the-less desirable that the fall crop should begin to ripen in August. In the Mountain sections of Virginia frosts frequently occur by October 15 and it would be desirable to have most of the crop ripened before that date. Many of the seedlings of Indian Summer crossed with varieties other than Ranere ripen their fall crop too late to be of value in the cooler sections of Virginia. Under favorable conditions of culture and moisture the period of ripening of the fall crop may be expected to extend over a period of more than a month.

## Summary

The Sunrise red raspberry appears to have a genetic factor or factors for the autumn-fruiting character imparted by Ranere, which differs from the factor or factors for that character possessed by Indian Summer, obtained from Lloyd George.

Because of the adaptation of Sunrise to environmental conditions prevailing in Virginia and the early ripening season of the fall crop produced by its seedlings, Sunrise appears to have promise as a parent in breeding autumn-fruiting red raspberries for Virginia.

## Literature Cited

1. Darrow, G. M., and Clark, J. H. The Sunrise red raspberry. *N. J. Agr. Exp. Sta. Cir.* 397. 1939.
2. Drain, B. D. Tennessee autumn red raspberry. *Tenn. Agr. Exp. Sta. Cir.* 70. 1940.

3. SLATE, G. L. Breeding autumn-fruiting red raspberries. *Proc. Amer. Soc. Hort. Sci.* 37: 574–578. 1939.
4. ———— Breeding autumn-fruiting raspberries; Third report. *Proc. Amer. Soc. Hort. Sci.* 51: 301–303. 1948.
5. ———— and SUIT, R. F. A second report on the breeding of autumn-fruiting red raspberries. *Proc. Amer. Soc. Hort. Sci.* 44: 283–288. 1944.
6. WALDO, GEO. F., and DARROW, GEO. M. Breeding autumn-fruiting raspberries under Oregon conditions. *Proc. Amer. Soc. Hort. Sci.* 39: 274–278. 1941.

# Transformation of Split-Plot Yield Data to Improve Analysis of Variance

By G. A. BAKER and G. C. HANNA, *University of California, Davis, Calif.*

SPLIT-PLOT designs are often used where planting dates and cultural methods are being tested. For example, Knott and Hanna (2) used such a design to test the effect of planting date and variety on the yield of center and side shoots of broccoli. The experiment has been reported elsewhere, with analysis of variance based on the assumption of homogeneity of variances. Salmon (3) has pointed out that it is common experience for yield to affect variance—that is, high yields are generally more variable than low yields. From casual examination, it appears that the yields for different planting dates vary to a point where the error variances may be different for the various planting dates.

It is the purpose of this note to investigate the probable nonhomogeneity of the error variances for different planting dates, to find a suitable transformation in case of nonhomogeneity in order to equalize the error variances, to call attention to the general necessity of considering the equality of the variances in such data, and to point out the greater logical consistency of such experiments when properly analyzed.

If the error variances for the different planting dates for the 1945–46 experiment are computed, we find:

| *Planting Date* | *Mean Yield (Pounds Per Plant)* | *Error Variance (Part of Error b)* |
|---|---|---|
| July | 0.8091 | 0.2483 |
| August | 0.5041 | 0.2331 |
| September | 0.2469 | 0.0843 |
| Total | | 0.5657 |

If we test these variances by the method of Hartley (4) we find $M = 5.28$ which is slightly below $M = 5.99$, the value necessary for significance at the 5 per cent level.

Similarly, the error variances for the 1946–47 experiment are:

| *Planting Date* | *Mean Yield (Pounds Per Plant)* | *Error Variance (Part of Error b)* |
|---|---|---|
| July | 1.0450 | 0.2462 |
| August | 0.6604 | 0.0773 |
| September | 0.2570 | 0.0452 |
| Total | | 0.3687 |

As before, $M = 9.24$—which is significant at about the 1 per cent level.

Because of these values of $M$, the apparent progression of the values of the error variances, and the wide observation of the general increase of variance with mean yield, we shall assume that variance increases as mean yield increases.

Bartlett (1) considers transformations from a general theoretical standpoint. He suggests using the square root transformation if the variance is proportional to the mean, and the logarithmic transformation if the variance is proportional to the mean squared. Other relationships between the variance and mean call for other transformations. The present data are somewhat scanty as far as determining the precise relationship between the mean and variance is concerned. Upon trial, it was found that the logarithmic transformation overcorrected the trend in the variances. That is, the trend was reversed so that the planting dates with large error variances now had small variances, and vice versa. The variances were just as nonhomogeneous as before.

The square root transformation seemed to work much better. The values of $M$, which measure the heterogeneity of the variances, dropped from 5.28 to 1.76 for the 1945–46 data and from 9.24 to 1.56 for the 1946–47 data. The analyses of variances are compared in the Table I.

TABLE I—COMPARISON OF ANALYSES OF VARIANCE OF BROCCOLI SPLIT-PLOT EXPERIMENTS BASED ON AVERAGE YIELDS OF SIDE SHOOTS AND ON THE SQUARE ROOTS OF THE AVERAGE YIELDS OF SIDE SHOOTS

| Variation Due to | Degrees of Freedom | Sum of Squares | Mean Squares | F | Sum of Squares | Mean Square | F | F (.05) | F (.01) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *1945–46* | | | | | |
| 1. Columns | 2 | 0.018790 | — | — | 0.020528 | — | — | — | — |
| 2. Replications | 2 | 0.156768 | — | — | 0.086354 | — | — | — | — |
| 3. Planting dates | 2 | 4.278632 | 2.139316 | 193.61 | 2.309268 | 1.154634 | 425.79 | 19.00 | 99.00 |
| 4. Error (a) | 2 | 0.022099 | 0.011050 | — | 0.005423 | 0.002712 | — | — | — |
| 5. Main plots | 8 | 4.476289 | — | — | 2.421573 | — | — | — | — |
| 6. Strain | 8 | 0.491848 | 0.061481 | 5.22 | 0.323117 | 0.040390 | 7.46 | 2.08 | 2.80 |
| 7. Strain × planting dates | 16 | 0.608676 | 0.038042 | 3.23 | 0.319415 | 0.019963 | 3.69 | 1.86 | 2.40 |
| 8. Error (b) | 48 | 0.565740 | 0.011786 | — | 0.259905 | 0.005415 | — | — | — |
| July | (16) | 0.248337 | — | — | 0.076826 | — | — | — | — |
| August | (16) | 0.233138 | — | — | 0.111654 | — | — | — | — |
| September | (16) | 0.084265 | — | — | 0.071430 | — | — | — | — |
| 9. Total | 80 | 6.142552 | — | — | 3.324010 | — | — | — | — |
| | | | | *1946–47* | | | | | |
| 1. Columns | 2 | 0.003964 | — | — | 0.002591 | — | — | — | — |
| 2. Replications | 2 | 0.012551 | — | — | 0.005177 | — | — | — | — |
| 3. Planting dates | 2 | 6.521144 | 3.260572 | 730.45 | 2.917935 | 1.458967 | 1899.23 | 19.00 | 99.00 |
| 4. Error (a) | 2 | 0.008928 | 0.004464 | — | 0.001536 | 0.000768 | — | — | — |
| 5. Main plots | 8 | 6.546587 | — | — | 2.927239 | — | — | — | — |
| 6. Strain | 6 | 0.585640 | 0.097607 | 9.53 | 0.276440 | 0.046073 | 12.35 | 2.36 | 3.35 |
| 7. Strain × planting dates | 12 | 0.497796 | 0.041483 | 4.05 | 0.258305 | 0.021525 | 5.77 | 2.03 | 2.72 |
| 8. Error (b) | 36 | 0.368726 | 0.010242 | — | 0.134311 | 0.003731 | — | — | — |
| July | (12) | 0.246153 | — | — | 0.061380 | — | — | — | — |
| August | (12) | 0.077351 | — | — | 0.029825 | — | — | — | — |
| September | (12) | 0.045222 | — | — | 0.043106 | — | — | — | — |
| 9. Total | 62 | 7.998749 | — | — | 3.596295 | — | — | — | — |

It is noticed that the F values are considerably increased in all cases. In this particular experiment no important F was changed from "nonsignificance" to "significance" by the use of the square root transformation. In other instances, the use of a transformation to make the variances in the different parts of an experiment more nearly uniform might completely change the whole interpretation of the ex-

periment. The purpose of the use of such transformations is, of course, to bring the observed data into conformity with the assumptions of the mathematical model that is the basis of the usual analysis of variance and not simply to juggle figures to get larger F values. A proper transformation in this case clarifies the point at issue. In other cases, if care is not exercised in considering all technical details, the interpretation of the data may be obscured instead of clarified.

Another evidence of the rectifying effect of the square root transformation is the relation between the error variances (b) for the 1945–46 and 1946–47 experiments. In 1945–46, 20 plants were grown per row, and in 1946–47 40 plants were grown per row. Thus, except for possible increase in soil variability, we would expect the variance for 1946–47 to be half that for 1945–46. In the straight analysis of variance the ratio of the 1946–47 variance to the 1945–46 variance is 0.87, while for the analysis based on the square root transformation the ratio is 0.69.

From the results of the detailed consideration of these experiments, where the differences in "treatments" were great enough to produce significant differences in error variances due regard must be given to the uniformity of variance in the analysis of variance. If this is not done, important effects may be overlooked, or improperly assessed, or completely misinterpreted.

After the best possible statistical methods have been used to determine statistical significance it is up to the investigator or grower to determine whether the increase is worth the effort and expense from the standpoint of economy and practicability.

## Literature Cited


1. Bartlett, M. S. The use of transformations. *Biometrics* 3: 39–52. 1947.
2. Knott, J. E., and Hanna G. C. The influence of various summer planting dates on the yield of broccoli strains. *Proc. Amer. Soc. Hort. Sci.* 51: 428–432. 1948.
3. Salmon, S. C. Generalized standard errors for evaluating bunt experiments with wheat. *Jour. Amer. Soc. Agron.* 30: 647–663. 1938.
4. Thompson, Catherine M., and Merrington, Maxine. Tables for testing the homogeneity of a set of estimated variances. Prefatory note written by H. O. Hartley and E. S. Pearson. *Biometrika* 33, Part *IV*: 296–301. *University College, London. University Press, Cambridge.* June, 1946.

# A Rating System for the Evaluation of Horticultural Material[1]

By E. B. Morrow, *North Carolina State College, Raleigh, N. C.*, George M. Darrow, *U. S. Department of Agriculture, Beltsville, Md.*, and J. A. Rigney, *North Carolina State College, Raleigh, N. C.*

Workers in the field of plant breeding are aware of the need for methods or techniques which quickly measure the expression of character differences in seedling progenies and in selected plants, lines, or varieties. When large numbers of progenies are grown it is seldom possible to make careful objective measurements on more than a few major characters. It is very desirable, however, to reduce to quantitative terms variations in as many characters as possible. A system of visually scoring or rating the individuals seems to offer a solution to this problem. This paper describes such a system, illustrates some types of characters on which it has been used, and indicates the degree of accuracy that was obtained. While such a system is not new, there are few published reports of the reliability of these techniques.

## Methods

In the application of this system to blueberries and strawberries, we rated characters on a score of 1 to 10. A score of 1 indicated the poorest and a score of 10 the best rating for a particular character. In an attempt to separate differences more clearly in the mind of the individual doing the rating, we have considered ratings of 1 to 5 to be below the limits for commercial usage and ratings of 6 to 10 to be within the range of commercial usage. For example, a rating of 4 or 5 for relative firmness in a strawberry selection would mean that it is too soft for shipment but it still might be fine for the home garden.

The scores may be handled in most cases just as any objective measurement to give averages and standard errors.

## Illustrations

Sample ratings from a strawberry variety test illustrating the use of this system in measuring the resistance to leaf spot are given in Table I. In establishing standards for leaf spot resistance, a rating of 1 has meant that approximately 90 to 100 per cent of the leaves were infected and that many of the leaves had been killed by the disease. A rating of 10 has indicated that the plants were free from infection or that the amount of spotting was extremely light. The midpoint between these two classes was the dividing line for ratings of 5 and 6. By using definite limits for each score, data for different years or locations may be compared. The experimental design at both McCullers and Willard was a 5 x 5 simple lattice with four replications. As in-

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TABLE I—SAMPLE RATINGS FOR RESISTANCE TO LEAF SPOT IN STRAWBERRY VARIETY TESTS (1945)

| Variety | McCullers | | Willard | |
|---|---|---|---|---|
| | Mean Rating | Range | Mean Rating | Range |
| Blakemore | 8.25 | 7–9 | 8.00 | 6–9 |
| Dorsett | 5.25 | 4–6 | 8.25 | 6–9 |
| Fairfax | 7.75 | 7–9 | 8.00 | 7–9 |
| Fairmore | 7.50 | 7–8 | 9.25 | 9–10 |
| Massey | 9.50 | 9–10 | 8.00 | 6–9 |
| Maytime | 8.00 | 8–8 | 4.25 | 3–6 |
| L.S.D. at .05 | 0.87 | — | 1.10 | — |
| Coefficient of variation | 8.4 | — | 9.1 | — |

dicated in the table, we measured differences at the 5 per cent level of slightly less than one point at McCullers and slightly over one point at Willard. The mean scores indicate definite varietal differences at each station and also a difference in the reaction among the varieties at the two locations.

The value of ratings in measuring the expression of blueberry characters is illustrated in Figs. 1, 2, and 3.

Scar type is an important character in blueberry fruits from the standpoint of ease of picking and keeping quality. If a large, deep scar is left when the berry is separated from the stem, it will not ship or keep as well as a berry with a small, dry scar. Scar type in highbush *(Vaccinium australe)* blueberry varieties and selections is generally much poorer than in rabbiteye *(V. ashei)* blueberries. In a comparison of 40 highbush selections with 52 rabbiteye selections, 83 per cent of the rabbiteye were given a rating of 10 while only 7 per cent of the highbush were given as high a rating (Fig. 1).

We have also used ratings of 1 to 10 in measuring berry color in blueberries. A rating of 1 indicates a shiny black and a rating of 10 a highly glaucous purple-blue. The rating system for color can be given stability from year to year by reference to standard color charts. The color of the most highly glaucous berries which we have seen are approximately equal to a *Value* of 6.5 and are within the *Chroma* range of 2 to 3 on the Munsell Purple-Blue chart. A score of 1 is comparable to a *Value* of 2 and a *Chroma* of 1 or 2 on this same chart. In contrast with scar type, the same 40 highbush selections all were within the range of 6 to 10. The 52 rabbiteye selections ranged from 1 to 10, with 41 per cent below a rating of 6 (Fig. 2).

In the rabbiteye blueberry there is a high degree of correlation between the amount of glaucescence on the leaf and fruit. Highly glaucous leaves are bluish-green and highly glaucous berries are a light purple-blue. We measured the correlation between leaf and fruit color by estimating the amount of glaucescence on a 1 to 10 basis. A rating of 1 indicated no glaucescence on either leaf or fruit and a rating of 10 indicated the most highly glaucous leaf or berry encountered in our experience. Data on 305 rabbiteye seedlings involving eight different parental combinations are given in Fig. 3. As indicated by Fig. 3, there was a very high degree of correlation ($r = .91$) between leaf and fruit color in these seedlings. This means that approximately 85 per cent of the variations in fruit color could be predicted from leaf ratings.

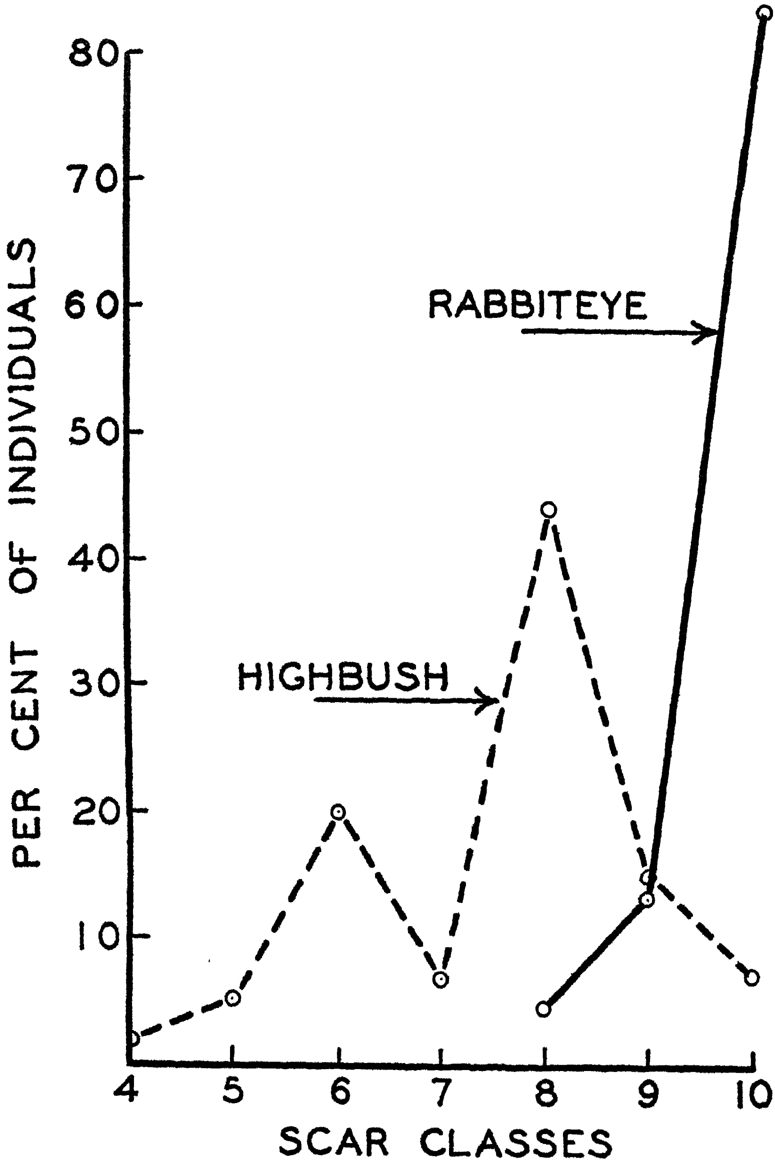


FIG. 1. Comparison of fruit scar ratings in highbush and rabbiteye blueberry selections.

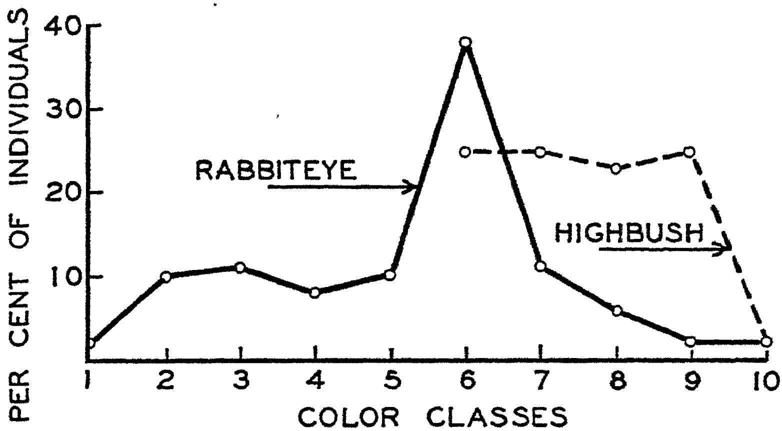


FIG. 2. Comparison of fruit color ratings in highbush and rabbiteye blueberry selections.

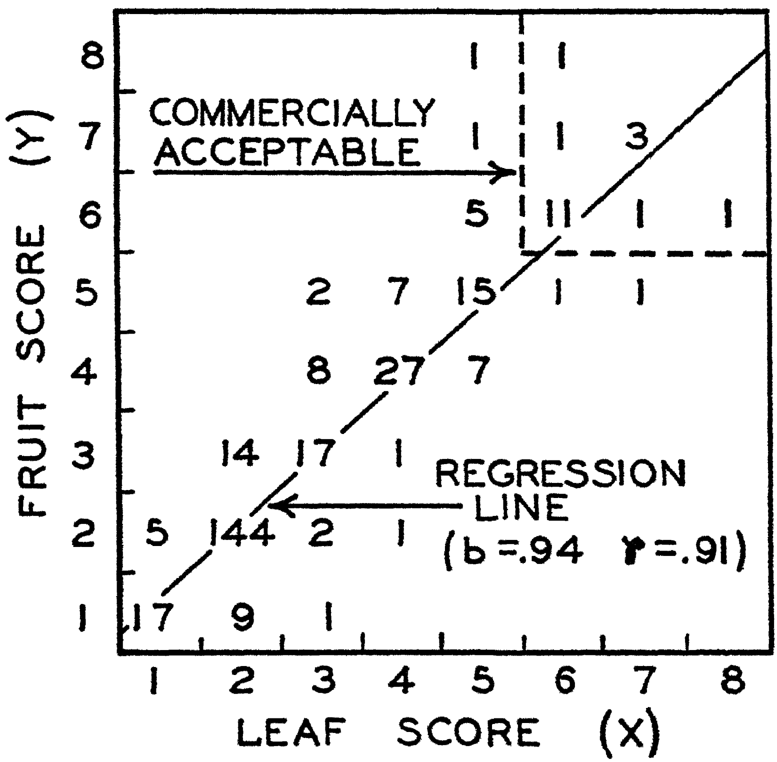


FIG. 3. Correlation of fruit and leaf color in rabbiteye blueberry seedlings.

The regression of fruit score on leaf score was very close to 1 ($b = .94$), indicating a direct relationship between the readings. If a rating of 6 is considered the lower limit for satisfactory color, a tremendous saving could be effected in breeding rabbiteye blueberries by growing to maturity only those seedlings with a leaf score of 6 or above.

## Discussion

A rating system based upon a scale of 1 to 10 has made it possible to measure rapidly many characters in blueberry and strawberry seedlings and varieties. The system is based upon visual or other sensory perception rather than on more laborious objective methods. Many characters may be measured fairly accurately by such a procedure, whereas more exact measurements would be prohibitive. In the early stages of selection within segregating populations it may be more efficient to sacrifice some accuracy of measurement to obtain data on a larger number of characters and individuals, Figs. 1 to 3.

The use of definite limits for each score is highly desirable, but not always possible. For example, flavor cannot be described objectively. In cases such as this, standard types or varieties must be used. This means that the base of reference changes from time to time as the standard is replaced. Types which are commercially acceptable today may be scored below 6 several years hence.

In the application of this system, we have not attempted to compile total scores for individuals based upon weighted ratings for a series of characters. While such a technique is frequently used, its value is proportional to the information available on the relative importance of each character entering into the total score. Most breeding projects are aimed at resolving specific problems and hence do not require the use of average over-all scores.

# The Volatility of Several Salts and Esters of 2,4–D As Determined by the Response of Tomato, Bean, and Cotton Plants

By Wendell R. Mullison, *Dow Chemical Company, Midland, Mich.*

There has been much interest shown in the volatility of 2,4–D (2,4–dichlorophenoxy acetic acid) and its derivatives due to their widespread use as weed killers. There have been reports of damage to crops in fields adjacent to those treated with 2,4–D for weed control. Dunlap (1) in his paper gives a good review and bibliography for cotton on this point. This damage has been attributed in some cases to the volatilization of the various 2,4–D derivatives (3). Thus it became of interest to carry out a laboratory investigation of the volatility of 2,4–D and several of its derivatives. These studies were made using young tomato, bean, and cotton plants.

## Materials and Methods

Round battery jars approximately 21 cm in diameter and 25 cm high with volumes of about 9.8 liters were used. These battery jars were inverted on panes of window glass about 30 cm square to form closed chambers. Inside such a chamber was placed a 13 cm petri dish containing a saturated solution of sodium hydroxide. In the center of the petri dish was placed a smaller petri dish about 5 cm in diameter. A sufficient amount of the 2,4–D compound being tested was added to cover the bottom of the smaller petri dish. This dish within a dish technique was designed to insure that if creeping of the compound should occur the material would not get outside the larger petri dish. Young plants were placed inside the chambers and exposed to the confined atmosphere for varying periods of time. The pots containing the plants were not allowed to touch the large petri dish and insofar as possible the plant foliage was kept from touching the walls of the chamber. Following the treatment the plants were removed from the chambers and put in a greenhouse for observation and study.

*Experiment I:*—Young tomato and bean plants were given a 65-hour exposure at room temperature (65 to 72 degrees F) to several 2,4–D derivatives and the data are given in Table I.

TABLE I—Responses of Tomato and Bean Plants Exposed 65 Hours to Various 2,4–D Derivatives at Room Temperature (65 to 72 Degrees F)

| Compound | Plant Responses at End of Treatment | | Plant Responses 24 Days After Treatment | |
|---|---|---|---|---|
| | Tomato | Bean | Tomato | Bean |
| 2,4-Dichlorophenoxy acetic acid | None | None | None | None |
| An alkanolamine salt of 2,4–dichlorophenoxy acetic acid | None | None | None | None |
| Sodium salt of 2,4-dichlorophenoxy acetic acid | None | None | None | None |
| Isopropyl ester of 2,4–dichlorophenoxy acetic acid | Epinasty*, stem curvature | Epinasty*, stem curvature | Dead | Dead |
| Untreated control | None | None | None | None |

*A positive reaction noted after 5 hours exposure.


FIG. 1. Tomato and bean plants treated at room temperature (65 to 72 degrees F) as indicated. Photographs were taken at the conclusion of the exposure period. Note the pronounced epinasty and stem curvature in the plants exposed to the isopropyl ester of 2,4-D. The slight stem curvature in some cases in the other treatments was due to a phototropic effect.

*Experiment II:*—Following the plan used in experiment I several aliphatic esters of 2,4–D were studied. The esters used were made from alcohols containing 1 to 5 carbon atoms. The effect of high temperature during the exposure period was also studied in this experiment. The chambers were put in a room where the temperature was kept at 100 ± 5 degrees F. The plants were given an exposure period of 22 hours. Results are given in Table II.


FIG. 2. Tomato plants photographed about 3 weeks after the indicated treatments. Note the normal appearance of leaves on the plants exposed to the sodium and alkanolamine salts of 2,4–D.

*Experiment III:*—Nastic movements had been noted after 3 hours exposure to several 2,4–D esters in experiment II. This experiment was designed to determine the exposure time necessary to cause such a response. Using the same techniques as before plants were given exposures to several aliphatic esters of 2,4–dichlorophenoxy acetic acid. The temperature was 100 ± 5 degrees F and the exposure times were ¼, ½, ¾, 1, 2, and 3 hours. Data are given in Table III. Inas-

TABLE II—RESPONSES OF TOMATO AND BEAN PLANTS EXPOSED FOR 22 HOURS AT 100 DEGREES F TO VARIOUS 2,4-D DERIVATIVES

| Compound | Plant Responses At End of Treatment | | Plant Responses 27 Days After Treatment | |
|---|---|---|---|---|
| | Tomato | Bean | Tomato | Bean |
| Sodium salt of 2,4-dichlorophenoxy acetic acid | None | None | None | None |
| An alkanolamine salt of 2,4-dichlorophenoxy acetic acid | None | None | None | None |
| Methyl ester of 2,4-dichlorophenoxy acetic acid | Epinasty,* stem curvature | Epinasty,* stem curvature | Dead | Dead |
| Ethyl ester of 2,4-dichlorophenoxy acetic acid...... .. .... . .... .. | Epinasty,* stem curvature | Epinasty,* stem curvature | Dying | Dead |
| Isopropyl ester of 2,4-dichlorophenoxy acetic acid | Epinasty,* stem curvature | Epinasty,* stem curvature | Dead | Dead |
| n-Butyl ester of 2,4-dichlorophenoxy acetic acid | Epinasty,* stem curvature | Epinasty,* stem curvature | Severe stunting stem swelling leaf modification | Severe stunting stem swelling leaf modification |
| n-Amyl ester of 2,4-dichlorophenoxy acetic acid | Epinasty,* stem curvature | Epinasty,* stem curvature | Severe stunting stem swelling leaf modification | Severe stunting stem swelling leaf modification |
| Isopropyl ester of 2,4,5-trichlorophenoxy acetic acid | Epinasty,* stem curvature | Epinasty,* stem curvature | Stunting stem swelling | Dead |
| Untreated control | None | None | None | None |

(*Nastic movements evident after 3 hours exposure )

TABLE III—TOMATO AND BEAN PLANT RESPONSES TO VARIOUS EXPOSURE PERIODS TO SEVERAL 2,4-D DERIVATIVES AT 100 DEGREES F

| Compound | Time (Hrs) | Plant Response 1 Day After Treatment | | Plant Response 21 Days After Treatment | |
|---|---|---|---|---|---|
| | | Tomato | Bean | Tomato | Bean |
| Methyl Ester of 2,4-dichlorophenoxy acetic acid | ¼ | +* | 0 | + | + |
| | ½ | + | 0 | + | + |
| | ¾ | + | + | + | + |
| Ethyl ester of 2,4-dichlorophenoxy acetic acid | ¼ | 0 | 0 | + | 0 |
| | ½ | + | 0 | + | + |
| | ¾ | + | + | + | + |
| Isopropyl ester of 2,4-dichlorophenoxy acetic acid | ¼ | + | 0 | + | 0 |
| | ½ | + | 0 | + | + |
| | ¾ | + | + | + | + |
| n-Butyl ester of 2,4-dichlorophenoxy acetic acid | ¼ | 0 | 0 | 0 | 0 |
| | ½ | 0 | 0 | 0 | 0 |
| | ¾ | + | + | + | + |
| n-Amyl ester of 2,4-dichlorophenoxy acetic acid | ¼ | 0 | 0 | 0 | 0 |
| | ½ | 0 | 0 | 0 | 0 |
| | ¾ | + | + | + | + |
| Isopropyl ester of 2,4,5-trichlorophenoxy acetic acid | ¼ | 0 | 0 | 0 | 0 |
| | ½ | 0 | 0 | 0 | 0 |
| | ¾ | + | + | + | + |

*+ = = "Hormone" action.
0 = No "hormone" action.

much as the responses were positive for all exposure periods longer than ¾ hours, data for the 1, 2, and 3 hour treatments are omitted in the table.

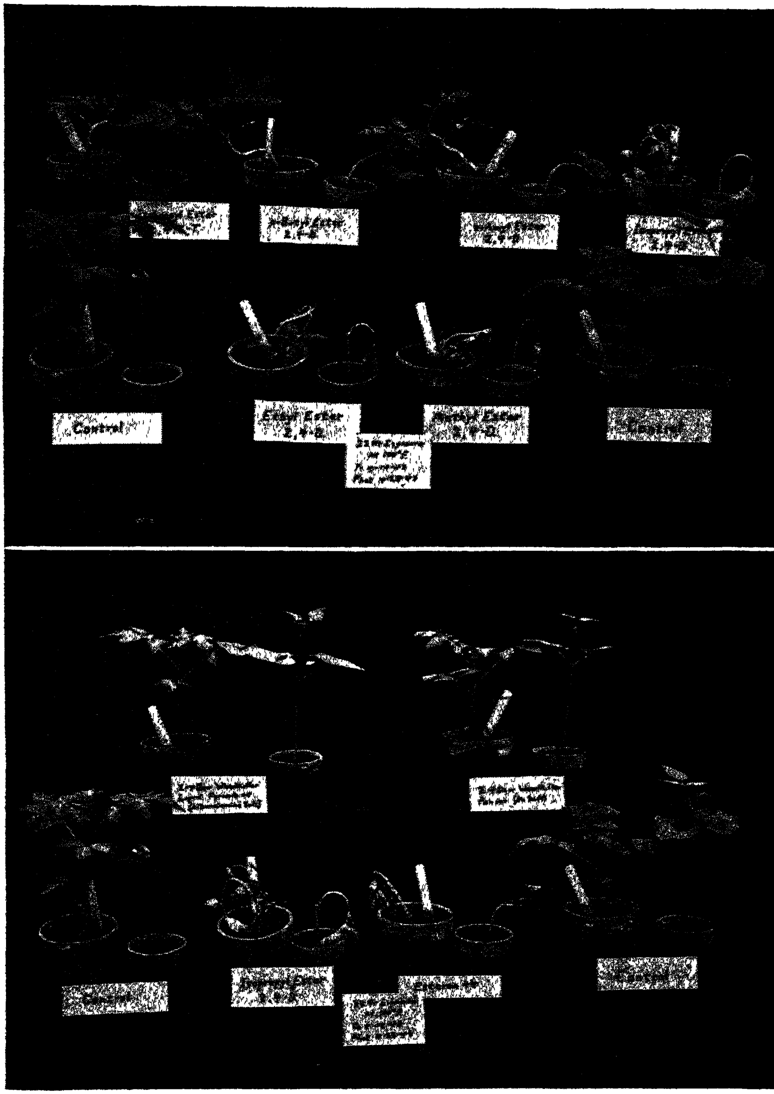


FIG. 3. Tomato and bean plants exposed for 22 hours at 100 degrees F to the vapors from the indicated compounds. Note the formative effects brought about by certain of the treatments. One of the control bean plants was diseased.

This experiment was partially repeated at room temperature (73 to 80 degrees F) but using only the methyl ester of 2,4-dichlorophenoxyacetic acid. When the experiment was done at this lower temperature a longer exposure period was necessary to cause a response equivalent

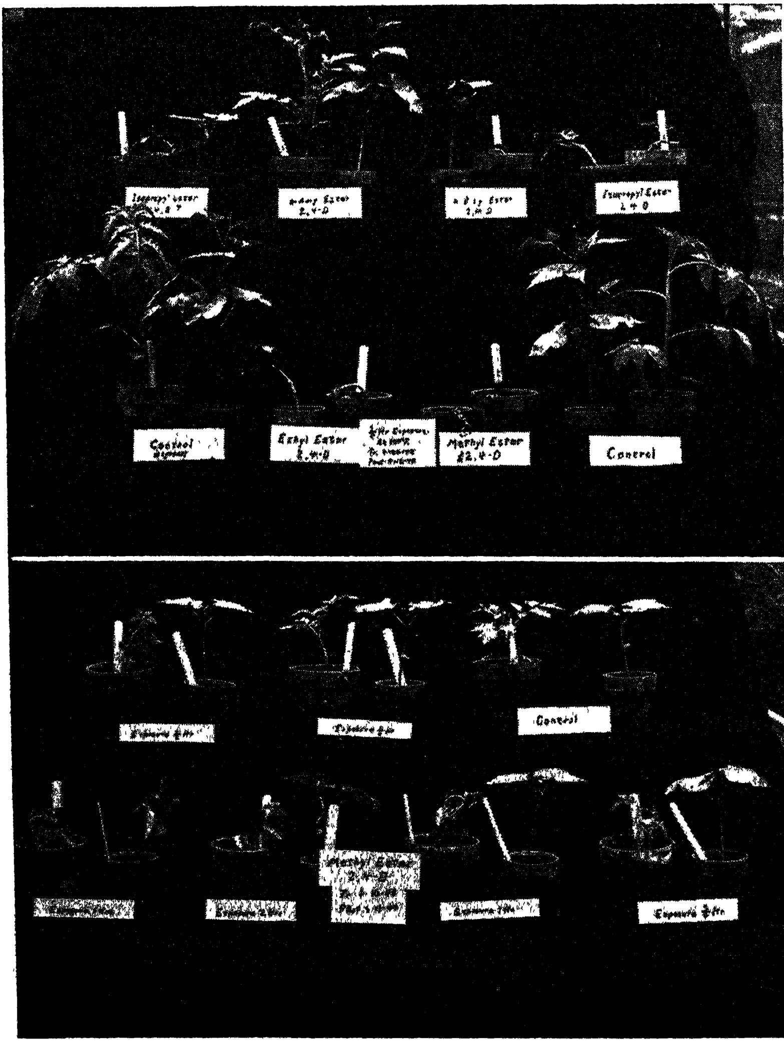

FIG. 4. The upper photograph shows the gradation in the symptoms from the methyl to the n-amyl ester of 2,4-D and the reaction to the isopropyl ester of 2,4,5-trichlorophenoxy acetic acid.

Note in the lower photograph that at room temperature (70 to 80 degrees F) an exposure of ½ hour to the methyl ester was sufficient to cause epinasty of tomato leaves.

to that obtained at 100 degrees F. For example, at this room temperature it took ½ hour exposure to bring about a "quick" response with tomato and 2 hours exposure to cause a "quick" response with beans.

*Experiment IV:*—Using the same techniques, young cotton plants

were exposed to the vapors of several 2,4–D derivatives for a 24-hour period at room temperature. Data are given in Table IV.

TABLE IV—Cotton Exposed for 24 Hours at Room Temperature (65 to 75 Degrees F) to Various 2,4–D Derivatives

| Compound | Plant Response at End of Treatment | Plant Response 53 Days After Treatment |
|---|---|---|
| Sodium salt of 2,4-dichlorophenoxy acetic acid | 0* | 0 |
| An alkanolamine salt of 2,4-dichlorophenoxy acetic acid | 0 | 0 |
| Isopropyl ester of 2,4-dichlorophenoxy acetic acid | + | + |
| Isopropyl ester of 2,4,5-trichlorophenoxy acetic acid | + | + |
| Untreated control | 0 | 0 |

*+ = "Hormone" response.
0 = No "hormone" response.

## Discussion

It is easily possible to contaminate any or all of the plants being used in connection with studies on 2,4–D and its derivatives due to the potent activity even at extremely low concentrations of these chemicals. Every precaution should be taken to avoid contamination. This is particularly true when using plants that are very sensitive to 2,4–D, such as tomatoes and cotton. Although this was done, it was found that one experiment had to be discarded when the untreated controls showed slight leaf modification.

These results strongly indicate that when unsprayed plants are bordering or near treated plants they will not be affected due to volatilization of 2,4–dichlorophenoxy acetic acid, its sodium or alkanolamine salt, and when 2,4–D damage to such plants has occurred it probably has been due to spray drift, dust drift or some other accidental means of contamination. Thus, the experimental data obtained under rigorous laboratory conditions completely supports Staten's field studies as to the non-volatility of the 2,4–D acid or its salts. Which ester of 2,4–D Staten used and found to be volatile was not stated in his paper, but presumably it was one of the esters used in this study.

An experiment (2) designed to determine by weighing the loss of material by volatilization indicates that 2,4–dichlorophenoxy acetic acid and its triethanolamine salt are non-volatile. In contrast to this the isopropyl ester of 2,4–dichlorophenoxy acetic acid lost an appreciable amount of weight.

It appears that the tomato is more sensitive than cotton for quick nastic responses to 2,4–D, that is, 24 hours after application. Comparing their subsequent sensitivity to 2,4–D as shown by leaf modification, cotton is more sensitive than tomato. Unfortunately, cotton plants do not grow well, even in the summer, at Midland, Michigan, and it was not feasible to make extensive use of them in this study. The bean plant is far less sensitive to 2,4–D as far as gross morphological responses are concerned compared to either tomato or cotton plants.

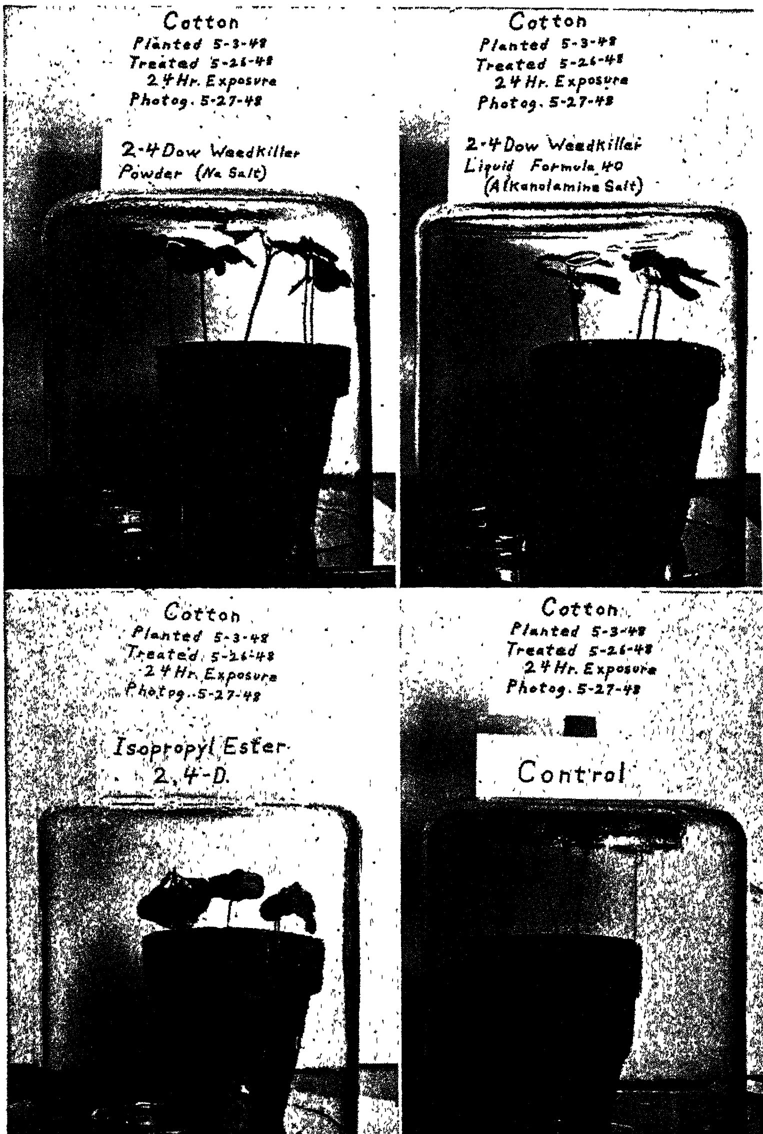


FIG. 5. Cotton plants treated as indicated and photographed at the end of the treatment. Note the drooped, folded appearance caused by the epinasty of the cotton plants exposed to the isopropyl ester of 2,4–D and its absence in the other treatments.

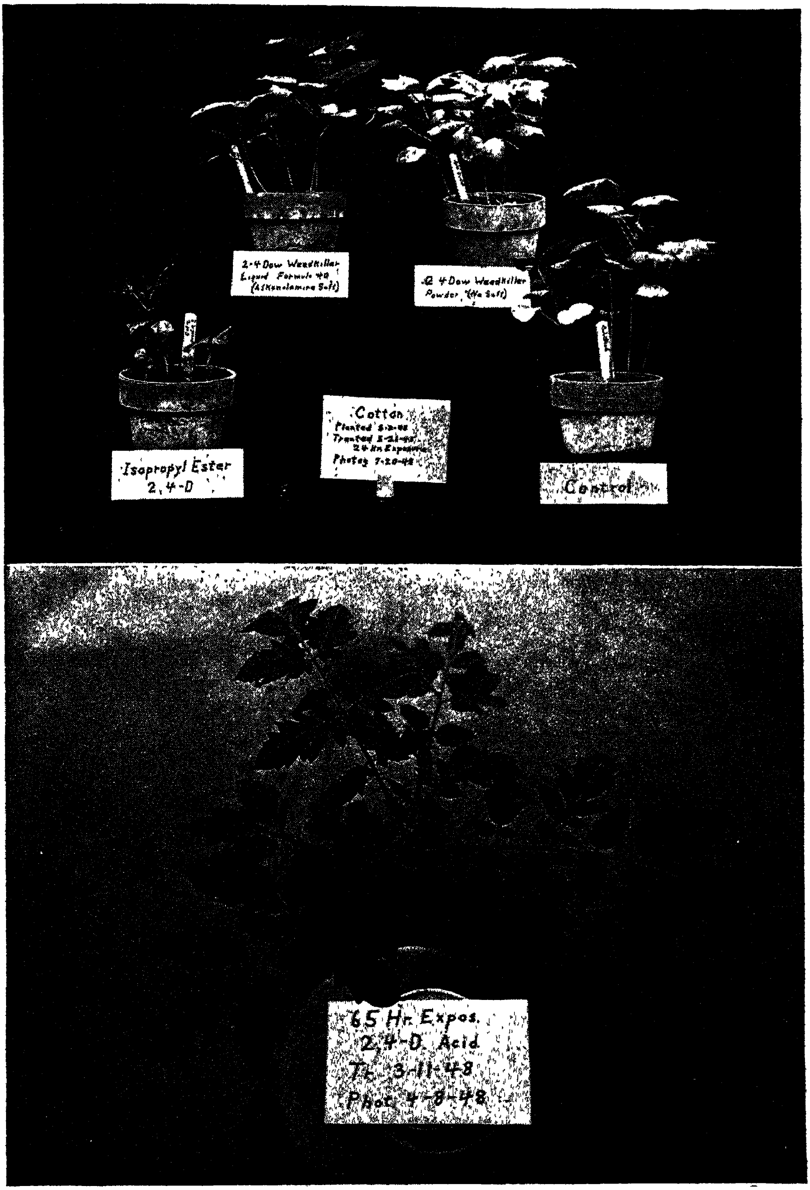


FIG. 6. The upper photograph shows the same cotton plants as in Fig. 5 about 2 months later. All the plants were severely infested with two-spotted spider mite. Note the pronounced formative effects in the plants exposed to vapor from the isopropyl ester of 2,4–D.

The lower photograph, taken about 1 month after treatment, shows a tomato plant exposed to 2,4–dichlorophenoxy acetic acid for 65 hours at room temperature (65 to 72 degrees F). Note the normal foliage.

## Summary

1. An alkanolamine salt and the sodium salt of 2,4–dichlorophenoxy acetic acid were non-volatile as determined by the responses of tomato, bean, and cotton plants.

2. Aliphatic (1–5 carbon) esters of 2,4–dichlorophenoxy acetic acid and the isopropyl ester of 2,4,5–trichlorophenoxy acetic acid were sufficiently volatile to cause decided plant responses.

3. The short exposure periods of 15 minutes at 100 degrees F, or 30 minutes at room temperature (73 to 80 degrees F) to the vapors of the methyl ester of 2,4–dichlorophenoxy acetic acid were sufficient to cause plant responses.

4. These experiments indicate that as the number of carbon atoms in the aliphatic portion of the 2,4–D ester is increased the volatility decreases.

5. The results of these experiments strongly indicate that unsprayed plants adjacent to or in the vicinity of plants treated for weed control will not be affected due to volatilization of 2,4–dichlorophenoxy acetic acid, its sodium, or alkanolamine salt.

## Literature Cited

1. Dunlap, A. A. 2,4-D injury to cotton from airplane dusting on rice. *Phytopath.* 38: 638–644. 1948.
2. Mullison, W. R., and Hummer, R. W. Some effects of the vapor of 2,4–dichlorophenoxy acetic acid derivatives on various field crop and vegetable seeds. *Bot. Gaz.* (in press).
3. Staten, G. Contamination of cotton fields by 2,4-D or hormone-type weed sprays. *Jour. Amer. Soc. Agron.* 38: 536–544. 1946.

# A Thresher for Small Lots of Seed

By Glen N. Davis and Caesar Cuneo, *University of California, Davis, Calif.*

To answer the need for a machine which could be used to thresh seed from parts of a plant, from individual plants or a small number of plants, the thresher illustrated in Figs. 1 and 2 was designed and built in the Division of Truck Crops of the University of California in the summer of 1947. The machine was constructed principally for threshing onion and carrot seed.

The principle of operation is as follows: the seeds are broken from the stalks and placed in the hopper *H* and fed onto rubbing table *D* by an agitator driven by the pulley *B*. Rubbing table *D* is stationary and remains in a fixed position while the machine is in operation. The actual "rubbing out" of the seed is accomplished by plate *C* mounted on rollers *R* and driven from an electric motor by arm *E*. Both halves of the rubbing apparatus *(C* and *D)* are covered with corrugated rubber floor matting to prevent injury to the seed. The amount of pressure exerted on the seed is controlled by adjusting the spring tensions *T*, through arms *A* to plate *C*.

To insure proper operation plate *C* must be driven by the motor revolving in such a direction that arm *E* begins its forward motion (toward the hopper) at the bottom of the stroke as indicated below *D*. In this position arm *E* presses on the back of plate *C* which is lifted up off the base *D* by rollers *R*. Plate *C* then moves forward to the hopper without contact with base *D*. As arm *E* begins the return half of the stroke, it is lifted from the back of plate *C* allowing *C* to contact base *D*. In other words the rubbing action takes place in only one direction — away from hopper *H*. Such action engages additional seed at each stroke and gradually works the seed from the hopper to the back of base *D* where it falls into receptacle *O*.

The amount of rubbing each lot of seed obtains is controlled somewhat by adjusting the angle of the working parts at point *L*. The opposite end is fastened to the welded steel frame with a pair of ordinary hinges.

The machine may be easily cleaned between different lots of seed by disengaging the steel bar from the slots in the tip of arms *A*, grasping the plate on which the rollers *R* are mounted and lifting plate *C*, giving ready access to stationary base *D*.

To facilitate moving from place to place two small steel wheels are mounted on the base of the legs at the end opposite the motor.

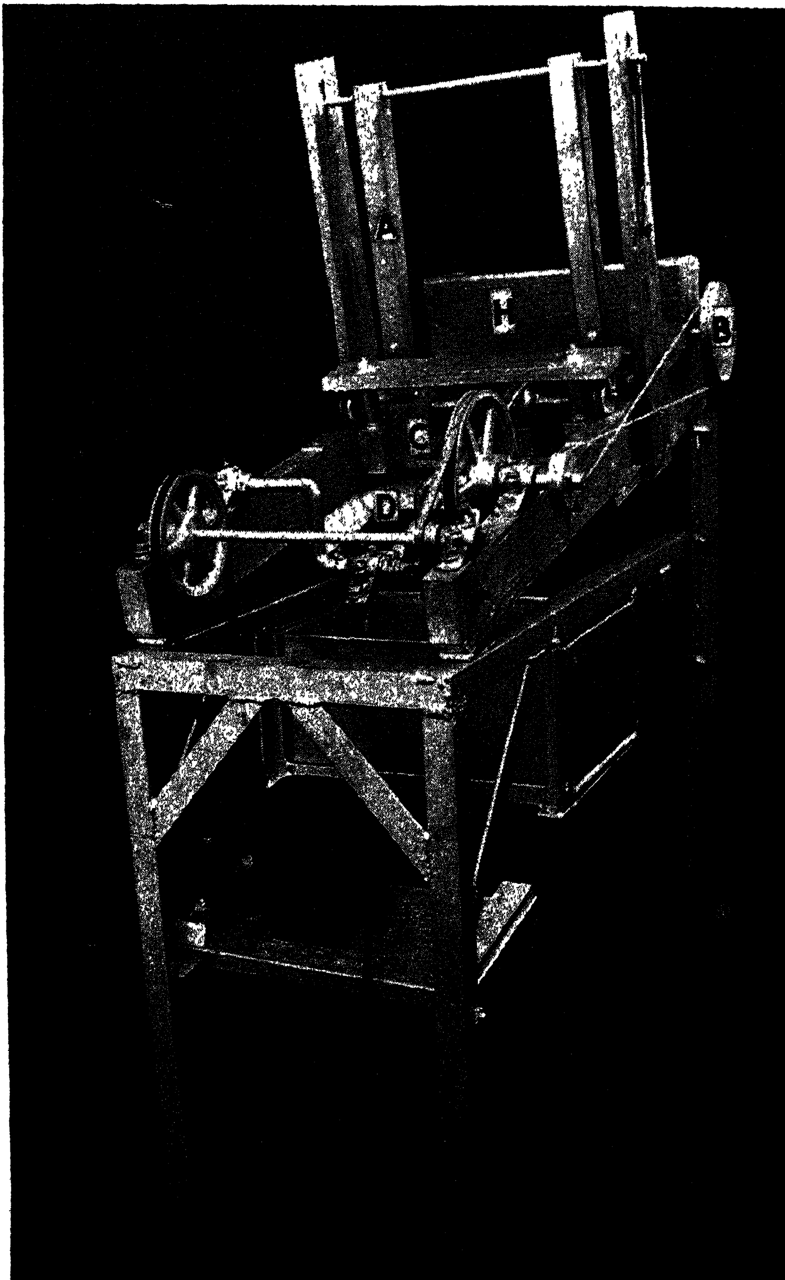


FIG. 1. End view of seed thresher.

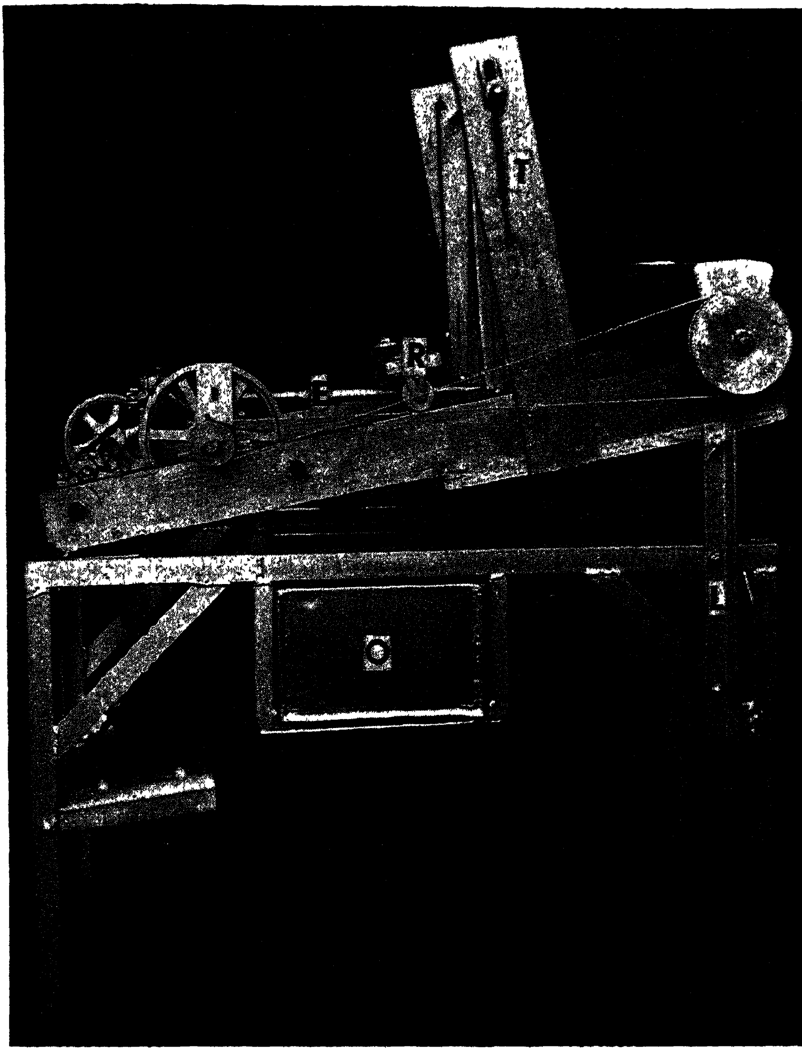


FIG. 2. Side view of seed thresher.

# The Herbicidal Action of Oils[1]

By Wm. Harold Minshall and V. A. Helson, *Dominion Department of Agriculture, Ottawa, Canada*

Oils have been used to kill weeds selectively in crops of carrots and of parsnips (4, 6, 10, 17, 25), in lawns (19, 20), in guayule nurseries (2), in cranberry bogs (7, 8), and in conifer seedling nurseries (23). The work of Crafts and Reiber (5) suggests that certain oil fractions may be used to kill weeds selectively in flax and onion crops. Oils have also been used quite extensively in a non-selective capacity, to kill all vegetation in such places as along railroads, on ditch banks, on roadsides, and in citrus orchards.

Because of the importance that oils are assuming in the herbicidal field, it would appear that a brief discussion of their herbicidal action merits consideration.

## The Composition of Oils

Naturally-occurring crude petroleum is composed of a multitude of individual compounds composed of carbon and hydrogen, called hydrocarbons. By means of distillation, crude petroleum is separated into the following fractions: gas, gasolene, kerosene, gas-oil, lubricating oil, and asphalt residuum. These fractions may be subjected to additional distillations, to cracking processes, or to various chemical treatments in order to produce the desired finished product. Petroleum oils may differ according to the refining process to which they are subjected and to the oil field from which they are derived. Thus, when we speak of herbicidal oils, we are not referring to a single compound but to a large number of complex mixtures, composed of individual hydrocarbons. This circumstance, of course, greatly complicates the correlating of results obtained in different geographical areas, and makes difficult the drawing up of specifications for herbicidal oils or of uniform instructions for their application as herbicides.

Most of the petroleum oils used as herbicides belong to the kerosene or gasolene fractions. They are low in viscosity and surface tension, and have affinities for the cutinized or suberized surfaces commonly found on plants. When applied to plants, they spread rapidly and completely wet the foliage.

According to Chapman and Pearce (3), it was early learned in the insecticidal field that the safeness of oil applications to plant leaves was related to the unsaturated constituents, particularly the aromatic content of the oil. This view has been fairly well substantiated in the herbicidal field from studies on the effect of different hydrocarbons, oil fractions, and distillates on plants (5, 11).

## The Penetration of Oils into the Leaves of Plants

According to Knight *et al* (15), the resistance offered to the penetration of oils deposited on leaves is mostly epidermal. The xerophytic leaves of stonecrop (*Sedum* sp.) showed no visible penetration of

[1]Contribution No. 959 from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.

kerosene after 8 hours of exposure, but, when the epidermis was punctured, penetration was very rapid. Turrell (26) studied the stomatal shape and pore size of citrus leaves and concluded that citrus stomata may be penetrated by oil.

Kerosene-like oils penetrate very rapidly the leaf epidermis of herbaceous plants rich in stomata. The penetration of oils is not, however, confined to stomata, as the cuticle may be penetrated to some extent (9, 14, 15, 24). Knight and Cleveland state (16) that surface tension and viscosity determine the rate of oil penetration.

Following the penetration of leaf epidermis, the oil spreads out and fills the intercellular spaces more or less completely (14, 24). This displacement of the air in the intercellular spaces by the oil renders the leaves translucent.

## The Distribution of Oil Following Penetration

Oils that penetrate into plant leaves may remain in the leaf indefinitely, may evaporate into the surrounding air, or may move out into other parts of the plants. No information on the rate of disappearance of herbicidal oils from leaves, or on the amounts of oil that may disappear by evaporation or transport to other plant parts, has been found in the literature. Rohrbaugh (24) found that from two-thirds to three-quarters of the lighter insecticidal oil emulsions applied to leaves of the orange disappeared during the first 3 months and that very little was left after 6 months. Knight *et al* (15) stated that of four lubricating oils applied to orange leaves the first, second, and third had disappeared in 65, 107, and 121 days respectively; a large quantity of the fourth was still present on 257 days after application. Young (28) reported that kerosene disappeared from potato leaves in from 1 to 24 hours but that lubricating oils remained in the leaves for the remainder of the growing season. The evaporation of insecticidal oils from leaves into the surrounding air is considered negligible (14, 15, 27) and, with certain insecticidal oils, at least a part of the oil remains in the leaf through the whole of its lifetime (15, 24, 27).

There is considerable evidence that, for certain plants at least, oils will move out of the leaves to other parts of the plant. Knight *et al* (15) were of the opinion that this movement was through the vascular system, the oils being translocated to the storage tissues. Rohrbaugh (24) and Young (27, 28, 29), however, found that the major portion of the oil moved by way of the intercellular spaces while it was being transported out of the leaves. Reports that at least a part of the oil enters the living cells are to be found (15, 21, 27, 28, 29), but, in most of them the evidence is not too definite. Young (29) has postulated an "oil-mass theory" of penetration of petroleum oils into the protoplasm of living cells, but Rohrbaugh (24) could find no evidence that oil entered plant cells that contained living protoplasm.

At Ottawa, the movement of kerosene-like oils has been studied in dandelions, carrots, and parsnips. By the use of Sudan IV dissolved in the oil, it has been found that, when the oil is applied to the leaves of the dandelion plant it travels from the leaves to the roots; and that, if the oil is applied to the cut surface of the root, it travels up to

and spreads throughout the leaf blades. During transport, the oil is confined to the intercellular spaces of parenchyma tissue in the midrib and petiole of the leaves and to the intercellular spaces of the phloem parenchyma tissue of the root. This transport of oil is not associated with either the xylem vessels, the sieve tubes, or the latex system. The diffusion of the oil within the root is not confined to any one direction but may take place up or down the root, in a radial direction, or tangentially around the root. In large turgid dandelion roots the rate of diffusion is from 4 to 5 centimeters per hour.

In carrots and parsnips, kerosene oils will also travel from the leaves to the roots, or vice versa, by means of the intercellular spaces of the parenchyma tissue. Oil has been found in an occasional trachae of the xylem of both leaves and roots, but the major portion of the oil that appears in their roots travels between the cells of their parenchyma tissues.

In all three plants, carrots, parsnips, and dandelions, no oil has ever been found inside living parenchyma cells.

## The Types of Oil Toxicity

deOng *et al* (22) found that the injury to the foliage of citrus trees from petroleum oils was of two distinct types — acute and chronic. Acute toxicity, which is caused by light, low-boiling oils, produces a rapid burning of the leaves and may be fatal within 48 hours. Chronic toxicity is caused by heavy high-boiling oils and produces a slow yellowing of the leaves with defoliation beginning after a few days. Similar toxicity types resulting from the use of oils in the herbicidal field have been observed by Crafts and Reiber (5). In fact these authors point out that several types of toxicity are involved rather than just two.

## The Effect of Oils on the Physiology of Plants

Addicott (1) studied the effects of oils on the cells of guayule leaves. He found that injury was evident within 30 minutes and that, at the end of this period, the palisade cells were in the early stages of collapse. The leaf tissues most affected were in those areas that came in direct contact with the oil. Injury was characterized first by a collapse and shrinkage of the entire cell, including the cell wall, and later by a more or less complete cytolysis.

Following the application of a highly refined undiluted white oil to citrus leaves, Knight *et al* (15) found that transpiration was sharply decreased, respiration was enormously increased, and photosynthesis was temporarily inoperative. Kelley (13) applied oil emulsions to leaves of apple, pear, peach, plum, and sour cherry and found that the transpiration rate was retarded as much as 75 per cent when the spray was applied to the lower surface of the leaves, but had no effect when it was applied to the upper surface. The retarding of the transpiration rate was noticeable within 30 minutes after application of the oil. It has been reported that the respiration rate of apple leaves (12) and apple twigs (12, 21) increased following the application of insecticidal oil emulsions.

At Ottawa, we have studied the time course of photosynthesis and respiration for leaves of carrot, parsnip, common mustard, lamb's quarters, and common chickweed following the application of a petroleum naphtha (boiling range 300 to 400 degrees F). By means of an infrared absorption apparatus, readings were taken at ten second intervals after the application of the oil. For all the plants studied, photosynthesis ceased abruptly and completely immediately following the application of the oil. With parsnip, true photosynthesis started to recover within thirty minutes after the application, and was almost one-third of the original rate at the end of 3 hours. The photosynthetic rate of parsnip continued to increase until at the end of 48 hours it was approaching normal. There was no sign of wilting of parsnip leaves following treatment. With mustard there were indications of a slight temporary recovery of true photosynthesis starting within 30 minutes after treatment and continuing for approximately 1 hour. Following this temporary recovery, however, true photosynthesis completely ceased and did not recover. The leaves of mustard were definitely wilted 1 hour after the oil was applied.

The respiration rate of parsnip continued with little change for at least 3 hours after the application. With mustard, the respiration continued at the original rate for 1 hour after which time it gradually tapered off to zero on the death of the leaves, some 2 hours after the oil was applied.

Whatever disrupts the photosynthesis following the application of oil is apparently temporary in nature for carrots and parsnips but permanent as far as such weeds as mustard and lamb's quarters are concerned. Parsnips and carrots are thus able to survive the application of oil while the weeds are killed.

Further studies are in progress at the present time. When completed a full report on methods and results will be published.

## Literature Cited


1. Addicott, F. T. Anatomical effects of oil spray injury in guayule seedlings. *Phytopath.* 34: 697–9. 1944.
2. Benedict, H. M., and Krofchek, A. W. The effect of petroleum oil herbicides on the growth of guayule and weed seedlings. *Jour. Amer. Soc. Agron.* 38: 882–895. 1946.
3. Chapman, P. J., and Pearce, G. W. Oil sprays. *Agr. Chem.* 2: 17–20, 35–37. 1947.
4. Crafts, A. S., and Reiber, H. G. Toxicity of oils to carrots and weeds. *Calif. Agr. Col. Mimeo. Leaflet.* p. 1–3. 1944.
5. ——— Herbicidal properties of oils. *Hilgardia* 18: 77–156. 1948.
6. Cole, C. E., Doery, A. C., and McAlpin, D. M. Weed control in carrot crops. *Jour. Dept. Agr. Victoria Australia* 42: 494–496. 1944.
7. Cross, C. E. Control of cranberry bog weeds. *Cranberries* 9: 15. 1944.
8. Doehlert, C. A. Some progress in cranberry investigations in 1945. *Proc. Ann. Convention Amer. Cranberry Grower's Assoc.* 76: 23–25. 1945.
9. Ginsburg, J. M. Penetration of petroleum oils into plant tissue. *Jour. Agr. Res.* 43: 469–474. 1931.
10. Hardy, W. D. Control of weeds in carrot crops. *Agr. Gaz. New South Wales* 55: 470–473. 1944.
11. Havis, J. R. The herbicidal properties of certain pure petroleum hydrocarbons (preliminary report). *Public No. 293, Dept. Vegetable Crops, Cornell Univ., Ithaca, N. Y. (Mimeo.)*

12. KELLEY, VICTOR W. Effect of certain hydrocarbon oils on respiration of foliage and dormant twigs of the apple. *Ill. Agr. Exp. Sta. Bul.* 348: 369–406. 1930.
13. ———— Effect of certain hydrocarbon oils on the transpiration rate of some deciduous tree fruits. *Ill. Agr. Exp. Sta. Bul.* 353: 579–600. 1930.
14. KENDALL, J. C. Oil sprays. *N. H. Agr. Exp. Sta. Bul.* 262: 14. 1932.
15. KNIGHT, H., CHAMBERLIN, J. C., and SAMUELS, C. D. On some limiting factors in the use of saturated petroleum oils as insecticides. *Plant Phys.* 4: 299–321. 1929.
16. KNIGHT, H., and CLEVELAND, C. R. Recent developments in oil sprays. *Jour. Econ. Ent.* 27: 269–289. 1934.
17. LACHMAN, W. H. The use of oil sprays as selective herbicides for carrots and parsnips. *Proc. Amer. Soc. Hort. Sci.* 45: 445–448. 1944.
18. ———— The use of oil sprays as selective herbicides for carrots and parsnips II. *Proc. Amer. Soc. Hort. Sci.* 47: 423–433. 1946.
19. LOOMIS, W. E. The control of dandelions in lawns. *Jour. Agr. Res.* 56: 855–868. 1938.
20. ———— and NOECKER, N. L. Petroleum sprays for dandelions. *Science* 83: 63–64. 1936.
21. OBERLE, G. D., PEARCE, G. W., CHAPMAN, P. J., and AVENS, A. W. Some physiological responses of deciduous fruit trees to petroleum oil sprays. *Proc. Amer. Soc. Hort. Sci.* 45: 119–130. 1944.
22. DEONG, E. R., KNIGHT, H., and CHAMBERLIN, J. C. A preliminary study of petroleum oil as an insecticide for citrus trees. *Hilgardia* 2: 351–384. 1927.
23. ROBBINS, P. W., GRIGSBY, B. H., and CHURCHILL, B. R. Report on chemical weed control for conifer seedlings and transplants. *Mich. Agr. Exp. Sta. Quart. Bul.* 30: 237–240. 1947.
24. ROHRBAUGH, P. W. Penetration and accumulation of petroleum spray oils in the leaves, twigs, and fruit of citrus trees. *Plant Phys.* 9: 699–730. 1934.
25. SWEET, R. D., KUNKEL, R., and RALEIGH, G. J. Oil sprays for the control of weeds in carrots and other vegetables. *Proc. Amer. Soc. Hort. Sci.* 45: 440–444. 1944.
26. TURRELL, F. M. Citrus leaf stomata: structure, composition, and pore size in relation to penetration of liquids. *Bot. Gaz.* 108: 476–483. 1947.
27. YOUNG, P. A. Penetration, distribution, and effect of petroleum oils in apple. *Jour. Agr. Res.* 49: 559–571. 1934.
28. ———— Distribution and effect of petroleum oils and kerosenes in potato, cucumber, turnip, barley, and onion. *Jour. Agr. Res.* 51: 925–934. 1935.
29. ———— Oil-mass theory of petroleum-oil penetration into protoplasm. Amer. Jour. Bot. 22: 1–8. 1935.

# The Amount of Self-Pollination in Male-Sterile Onion Lines

By Alfred E. Clarke, *U. S. Department of Agriculture, Logan, Utah,* and L. H. Pollard, *Utah Agricultural Experiment Station, Logan, Utah*

In recent years there has been considerable interest in the utilization of the male-sterile character in the production of new hybrid varieties of onion on a commercial scale. Jones and Clarke (2) have described the way in which the character is inherited and have outlined a breeding program. In a later paper (3) they have reviewed the progress made in this field.

Several investigations (unpublished data) have found in genetically developed male-sterile lines of onion varieties certain plants that produced a little good pollen, and in some cases selfed seed has been obtained. This has made it important to determine the amount of selfing that might occur in a male-sterile line being used to produce hybrid seed.

## Materials and Methods

The amount of selfing can be measured accurately by the use of marker genes. In the present study genes governing bulb color were used. Clarke, Jones, and Little (1) showed that three major pairs of genes are involved in the development of pigment in the onion bulb; namely, *C-c, R-r,* and *I-i.* The dominant *C* gene is a basic color factor necessary for the production of any pigment. Consequently, all *cc* plants produce white bulbs. The dominant *R* gene, in the presence of *C,* is responsible for the production of red pigment; its allele *r* is responsible for yellow. The inhibiting factor *I,* first reported by Rieman (6), is partially dominant over *i.* All *II* plants produce white bulbs; *Ii* plants may produce some color, particularly around the neck of the bulb, but are readily distinguished from red and yellow. However, these heterozygous plants cannot always be distinguished with certainty from pure white.

In the present study a number of male-sterile lines of Early Yellow Globe and Yellow Sweet Spanish were crossed with several varieties that were known to carry the dominant *I* gene. The dominant white varieties used were Southport White Globe, White Sweet Spanish (Utah strain), and White Sweet Spanish (Cochise strain). Single heads of the plants being crossed were placed close together in a small cloth cage. Flies were used to facilitate crossing, as described by Jones and Emsweller (4). Since the yellow strains are true-breeding for yellow bulb color, they must belong to the genotype *iiCCrr.* Since the dominant white strains used in this experiment are homozygous for *I* they are true-breeding for white color regardless of the presence or absence of the *C* and *R* genes. In the cross yellow *(ii)* X dominant white *(II),* the $F_1$ plants will be intermediate *(Ii)*; that is, white with some traces of color. In the particular crosses used in this study the *Ii* bulbs showed a faint yellowish tint in the outer scales, particularly in the neck region, and have been classified as buff. The quantity of pig-

ment varied considerably in different bulbs, but all were very light in color, most being almost pure white. Any selfed bulbs must, of course, be yellow like the mother line and, as has been mentioned previously, can be readily separated from those that are buff.

## Experimental Results

The results obtained are summarized in Table I. Of the total population about 4.1 per cent of the bulbs are yellow and must have arisen from self-pollination. On the basis of random sampling, the fiducial or confidence limits, calculated by the method given by Ricker (5), are between 3.0 and 5.5 per cent when $P = 0.99$.

The male-sterile Yellow Sweet Spanish lines averaged 5.6 per cent selfs (Table I), while the male-sterile Early Yellow Globe lines averaged only 1.1 per cent. However, most lines of male-sterile Yellow Sweet Spanish, like the male-sterile Early Yellow Globe, gave few selfs. Three out of the 11 families from the cross male-sterile Yellow Sweet Spanish x Cochise White Sweet Spanish produced all of the yellow bulbs. Similarly, seven out of 18 families from the cross male-sterile Yellow Sweet Spanish x Utah White Sweet Spanish produced all of the 43 yellow bulbs. However, 40 of these yellow bulbs occurred in only four families which are shown in Table II. The three families which produced all of the 21 selfed bulbs from the cross male-sterile Yellow Sweet Spanish x Cochise White Sweet Spanish are also shown in Table II. This is strong evidence that the individual families differ in the number of selfs they produce and that families can be obtained from these crosses with few, if any, selfs. This was further confirmed by microscopic examination of the pollen of many male-sterile plants. In many samples no viable pollen was found, whereas in samples from other plants some staining pollen was observed.

TABLE I—AMOUNT OF SELFING IN MALE-STERILE LINES OF ONION (FARMINGTON, 1948)

| Cross | No. All Families | No. Families Producing One or More Yellow Bulbs | Bulbs in All Families (No.): White or Buff (Hybrids) | Bulbs in All Families (No.): Yellow (Selfs) | Bulbs in All Families (No.): Total | Per Cent Amount of Selfing | Per Cent Fiducial Interval P = .99 |
|---|---|---|---|---|---|---|---|
| Male-sterile Early Yellow Globe × Utah White Sweet Spanish | 6 | 4 | 225 | 5 | 230 | 2.2 | 0.4 to 6 1 |
| Male-sterile Early Yellow Globe × Southport White Globe | 11 | 1 | 332 | 1 | 333 | 0.3 | 0.0 to 2.2 |
| Total for male-sterile Early Yellow Globe lines | 17 | 5 | 557 | 6 | 563 | 1.1 | 0.3 to 2.8 |
| Male-sterile Yellow Sweet Spanish × Utah White Sweet Spanish | 18 | 7 | 898 | 43 | 941 | 4.6 | 3.0 to 6.7 |
| Male-sterile Yellow Sweet Spanish × Cochise White Sweet Spanish | 11 | 3 | 194 | 21 | 215 | 9.8 | 5.1 to 16.7 |
| Total for male-sterile Yellow Sweet Spanish lines | 29 | 10 | 1,092 | 64 | 1,156 | 5.6 | 4.0 to 7.6 |
| Total for all lines | 46 | 15 | 1,649 | 70 | 1,719 | 4.1 | 3.0 to 5.5 |

## Discussion

From a practical standpoint, the average amount of selfing for all lines (4.1 per cent) is low enough so that it should not present a seri-

ous problem in maintaining stocks and producing hybrid seed commercially. In alfalfa, Tysdal and Crandall (7) found that plants with 30 per cent self-fertility or less could be used satisfactorily in the production of hybrid seed.

When the supply of foreign pollen is limited, it seems likely that more selfing takes place because any viable pollen grains produced by the male-sterile mother plant would have a better opportunity to function owing to less competition. In the cages, in several cases, little crossing occurred. In lot 720 (Table II) only three seeds were ob-

TABLE II—AMOUNT OF SELFING IN SELECTED FAMILIES OF YELLOW × WHITE SWEET SPANISH HYBRIDS (FARMINGTON, UTAH, 1948)

| Cross | Lot No. | No. White or Buff Bulbs (Hybrids) | No. Yellow Bulbs (Selfs) | Total No. Bulbs |
|---|---|---|---|---|
| Male-sterile Yellow Sweet Spanish × Utah White Sweet Spanish | 698 | 52 | 10 | 62 |
| | 727 | 84 | 6 | 90 |
| | 728 | 17 | 8 | 25 |
| | 736 | 9 | 16 | 25 |
| Male-sterile Yellow Sweet Spanish × Cochise White Sweet Spanish | 701 | 4 | 10 | 14 |
| | 720 | 0 | 3 | 3 |
| | 726 | 9 | 8 | 17 |

tained and all three proved to be selfs. If the failure to obtain crossed seed in this case was caused by a poor supply of viable pollen within the cage, then it seems likely that a better seed set would have been secured under open-pollinated field conditions, and the percentage of selfs would have been reduced. Possibly, under commercial field conditions, the percentage of selfs would be less than that obtained in this experiment. However, additional evidence would be required to prove this point.

Evidence has also been presented to show that certain male-sterile plants tend to produce more selfs than others. By eliminating male-sterile lines in which there is a relatively large amount of selfing, the breeder should be able to reduce the amount of selfing still further.

## LITERATURE CITED

1. CLARKE, A. E., JONES, H. A., and LITTLE, T. M. Inheritance of bulb color in the onion. *Genetics* 29: 569–575. 1944.
2. JONES, H. A., and CLARKE, A. E. Inheritance of male-sterility in the onion and the production of hybrid seed. *Proc. Amer. Soc. Hort. Sci.* 43: 189–194. 1943.
3. ———— The story of hybrid onions. *U. S. D. A. Ybk.* 1943–47: 320–326. 1947.
4. JONES, H. A., and EMSWELLER, S. L. The use of flies as onion pollinators. *Proc. Amer. Soc. Hort. Sci.* 31: 160–164. 1934.
5. RICKER, W. E. The concept of fiducial limits applied to the Poisson frequency distribution. *Jour. Amer. Statist. Assn.* 32: 349–356. 1937.
6. RIEMAN, G. H. Genetic factors for pigmentation in the onion and their relation to disease resistance. *Jour. Agr. Res.* 42: 251–278. 1931.
7. TYSDAL, H. M., and CRANDALL, B. H. The polycross progeny performance as an index of the combining ability of alfalfa clones. *Jour. Amer. Soc. Agron.* 40: 293–306. 1948.

# Variations in Yield and Cutting Percentage of Sweet Corn Hybrids[1]

By E. S. HABER, *Iowa State College, Ames, Iowa*

MORE than one-half of all the sweet corn grown in the United States is grown for processing, and in the corn belt probably 90 per cent of the sweet corn is grown for processing. In general, earliness of a hybrid is not a factor which influences the canner or freezer in his choice of a variety, as is the case with market corn. The processor is concerned with three main characters which influence him in his choice of a variety: first, quality; second, cutting percentage; and third, yield. Quality will not be discussed here, as this is a rather intangible thing to measure.

Practically all of the corn is contracted by the processor with growers, to be grown by them and the snapped ears delivered to the factory. The contract price is based on a given price per ton of ears delivered to the factory. Time of delivery is agreed upon between processor and grower. The yield in tons per acre is of prime importance to the grower, but not so important to the processor. Income per acre to the grower depends on the yielding ability of the hybrid. To the processor this is not so important, because more acres can be contracted to obtain the needed tonnage to operate the factory. Cutting percentage, the amount of corn which can be processed from each ton of corn purchased, is of prime importance to the processor and of no great concern to the grower. At times when the margin of profit in the processed corn is small, a difference of 3 per cent in cutting percentage may mean the difference between profit and loss.

The aim of the sweet corn breeder must be to develop a hybrid which will be satisfactory to the grower because of good yielding ability, and which will be satisfactory to the processor because of good cutting percentage. It is plain to nearly everyone that hybrids will vary from year to year in yield, due to differences in growing conditions. It is not generally recognized that cutting percentage varies from year to year in the same hybrid. Furthermore, a reduction or increase in cutting percentage is not entirely associated with higher yields of corn. Too often the processor, in the trial of a new hybrid variety, will condemn it or will be favorably impressed because of the cutting percentage or, as the canner expresses it, in the number of No. 2 cans per ton of snapped corn that can be processed.

What are the factors which cause variation in cutting percentage in the same hybrid from one year to the next? Disease, such as smut in the ears, may reduce the cutting percentage some years. Heavily "smutted" ears will be left in the field by the grower when harvesting; but small infestations in the ears cannot be quickly and readily detected, and such ears will be delivered to the factory. Trimming of smutted ears or the "throw out" of whole ears will reduce cutting

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per cent. However, not all reduction in cutting percentage can be accounted for as readily as this.

In the following table the yield and cutting percentage of nine hybrids for a period of 5 to 8 years are presented. These hybrids are widely used in the corn belt for processing, particularly canning. The yearly yields and cutting percentages for each hybrid were

| Hybrid | 1941 | | 1942 | | 1943 | | 1944 | |
|---|---|---|---|---|---|---|---|---|
| | Tons Per Acre | Cutting Per Cent | Tons Per Acre | Curting Per Cent | Tons Per Acre | Cutting Per Cent | Tons Per Acre | Cutting Per Cent |
| Ioana | 4 68 | 37.7 | 4.89 | 34.2 | 3.50 | 33.2 | 6.89 | 30.2 |
| Goldencross | 3.97 | 33.8 | 4.05 | 31.8 | 2.63 | 33.2 | 6.05 | 29.3 |
| Tendermost | — | — | — | — | — | — | 6.29 | 31.9 |
| Illinois 8 × 6 | 2.95 | 38.0 | 3.28 | 35.8 | 1.77 | 29 4 | 3.21 | 32.7 |
| Iogent 27 | 3.11 | 27.4 | 4.50 | 34.6 | 3.06 | 34.2 | 4.05 | 31.3 |
| Silvercross | 2.61 | 31.9 | — | — | 2.35 | 28.8 | 4.08 | 33.6 |
| Illinois 14 × 13 | 4.48 | 43.3 | 5.00 | 33.7 | 3.52 | 27.2 | 5.09 | 31 4 |
| Iogreen 56 | — | — | — | — | 4.65 | 37.6 | 6.81 | 32.4 |
| Iogreen 16 | — | — | — | — | 4.70 | 36.4 | 5.89 | 31.9 |

| Hybrid | 1945 | | 1946 | | 1947 | | 1948 | | Tons Per Acre (Ave) | Cutting Per Cent (Ave) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Per Acre | Cutting Per Cent | Tons Per Acre | Cutting Per Cent | Tons Per Acre | Cutting Per Cent | Tons Per Acre | Cutting Per Cent | | |
| Ioana | 2.98 | 31.9 | 3.17 | 31.1 | 1.39 | 31.7 | 7.08 | 32.7 | 4.32 | 32.4 |
| Goldencross | 3.06 | 30.8 | 3.59 | 32.2 | 1.17 | 32.4 | 6.33 | 36.1 | 3.86 | 32.5 |
| Terndermost | 3.09 | 31.2 | 3.14 | 34.8 | 1.15 | 33.5 | 5.98 | 42.7 | 4.93 | 35.0 |
| Illinois 8 × 6 | 2.39 | 34.3 | 3.59 | 31.7 | 1.53 | 30.1 | — | — | 2.70 | 33.1 |
| Iogent 27 | 2.69 | 32.2 | 3.40 | 33.0 | 1.87 | 31.4 | — | — | 3.24 | 33.5 |
| Silvercross | 3.40 | 30.0 | 3.75 | 33.8 | 1.49 | 29.8 | 6.38 | 37.3 | 3.44 | 32.2 |
| Illinois 14 × 13 | 3.00 | 30.0 | 4.41 | 29.4 | 2.07 | 31.0 | 7.58 | 38.4 | 4.40 | 33.1 |
| Iogreen 56 | 3.89 | 34.8 | 5.36 | 38.2 | 1.70 | 34.0 | 9.42 | 43.7 | 5.31 | 36.8 |
| Iogreen 16 | 4.36 | 31.7 | 4.30 | 34.9 | 1.69 | 32.3 | 6.70 | 41.7 | 4.61 | 34.8 |

taken from the records of the sweet corn yield tests, which included many more experimental hybrids and less popular named hybrids. Each year the hybrids were planted in randomized blocks with five replicates of 20 hills in each replicate. Five seeds were sown per hill, with the hills 3 by 3 feet apart. When corn plants were 4 to 6 inches high, the plants were thinned to three plants per hill. Thus yields were based on a uniform stand. The corn was harvested at prime maturity for processing, usually 71 to 73 per cent moisture of kernels. The corn was planted on Clarion loam with an application of 300 pounds of 0-20-0 per acre, applied in a band when planted. Soil tests of this soil show sufficient available potash, so none was added. Also, fertilizer experiments have shown that sweet corn does not respond to potash applications in this soil. Nitrogen was sufficient, as indicated by soil tests and by lack of response of sweet corn to nitrogen applications in a fertilizer test. The nitrogen has been maintained through the use of manure and green manures such as soybeans or sweet clover plowed under. In other words, the corn was always planted on land in a good rotation.

All usable ears were picked, as they are in commercial fields. Only one picking was made, since that is the common practice in corn for the cannery in the Middlewest. The corn in commercial fields is picked with a mechanical sweet corn picker or picked by hand and

tossed into a wagon drawn by a tractor, so there is no chance for more than one picking. Therefore, in these experiments the practice used in harvesting commercial acreage was followed. All ears with usable corn are figured in the cutting percentage. No selection of outstanding typical ears of the hybrid were used for cutting percentage. Corn was removed from the ears after husking and silking, by means of a power rotary-head, whole-kernel cutter, identical with machines used in most factories. In other words, yields and cutting percentage are based on procedures identical with those followed in the commercial acreage. It is highly desirable to use this method because of practical applications from this experiment. The ratio of kernel size to cob was not determined, as this may be misleading. Other factors which influence cutting percentage are weight of husks and weight or length of shanks. Hybrids with heavy husks or long shanks influence cutting percentage from the commercial standpoint, so kernel-cob ratio is no indication of cutting percentage. The true cutting percentage can only be determined by the amount of corn going into the cans from each ton of corn delivered to the factory. In these experiments the same practice was followed.

In 1944, a favorable year for yields, cutting percentages of all hybrids were low. This can be accounted for by the amount of smut present in the ears. This was also a favorable year for the development of smut and necessitated a great deal of trimming and "throw out" of heavily smutted ears, accounting for the low cutting percentage. In 1941 yields per acre were lower than in 1942; but in 1942 cutting percentages were lower. In 1947, when heat and drouth cut yields drastically, yields were the lowest of any of the 8 years, and the cutting percentage was also low. There were no smutty ears or other soft corn rots in appreciable amounts to account for the low percentage. In 1948 yields averaged higher than in any of the 8 years, as did also the cutting percentage. In comparing only 1947 and 1948, one might conclude that high cutting percentage was associated with high yields. This is not a sound conclusion in studying the data presented for the 8 years.

When is there more corn per ton of snapped ears? When the weight of cobs and husks is smaller in proportion to the weight of the kernels of corn. Why are cobs and husks proportionately heavier or lighter than the corn in various years? This is a problem that cannot be answered by the data presented. The data are presented to emphasize that too often the processor bases his opinion of a hybrid on one season's performance, particularly with respect to cutting percentage. Factors, other than smut and soft corn rots, which influence cutting percentage are not clearly defined. Yields are definitely influenced by weather conditions, but it has been definitely pointed out that in these experiments tonnage and cutting percentage are not correlated.

# A Note on the Cytology and Systematic Relationships of the Carrot

By Thomas W. Whitaker, *U. S. Department of Agriculture, La Jolla, Calif.*

The cultivated carrot belongs to the collective species *Daucus carota* L. This species includes a large assemblage of forms of both the annual and biennial types. The cultivated biennial type seems to have been derived from the more primitive annual type by selection, although some investigators claim that hybridization with one of the closely related species, probably *D. maximus* Desf., has been involved in its ancestry. About 60 species of Daucus have been described, but it is generally agreed that only about one-half of these are valid, the remainder are subspecies and forms of *D. carota*. Daucus is primarily a genus of the Mediterranean region and southern Asia. However, one native species is found in North America (*D. pusillus* Michx.), and another (*D. montanus* Humb. & Bonpl.) occurs in both North and South America.

Zagorodskikh (7) has made an extended study of *Daucus carota*, and according to this author the most ancient group of the cultivated forms is the "anthocyanin carrot", widely spread in middle and southeastern Asia. It is particularly rich in forms in Afghanistan at the junction of the Himalaya and Hindu-Kush mountain ranges. The "anthocyanin carrot" contains two types of pigment: (a) anthocyanin — responsible for the violet or black color of the roots; and (b) anthochlors — producing yellow-fleshed roots. The plastid pigment, carotene, responsible for the production of orange-fleshed roots, is not found in this group.

With the assistance of several seed companies, interested individuals, and the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, we have assembled and cultured what appears to be a representative sample of the more important varieties as well as a number of wild forms of *Daucus carota*.

In the course of studying this material for the purpose of evaluating its usefulness in a plant breeding program, the writer has made a cytological examination of several of the wild forms and a few of the cultivated varieties. It is the purpose of the present note to report these findings, and correlate them with other cytological and systematic work recorded for this species.

In the varieties and forms listed in Table I there were nine pairs of chromosomes. The counts were made from pollen mother cells, either at the first or second meiotic division, and were obtained from aceto-carmine smear preparations. The material had previously been fixed for 24 hours in 1 : 3 aceto-alcohol fixing fluid.

The named varieties corresponded in all respects to the descriptions given for the respective types in the carrot "Type Book" (2). Cape Market was similar to some of the poorer commercial strains of the

TABLE I—CARROT VARIETIES AND FORMS INVESTIGATED

| Variety or Number | Source | Origin |
|---|---|---|
| Danvers Red Core | Associated Seed Growers, Inc. | —— |
| Imperator | Associated Seed Growers, Inc. | —— |
| Long Orange | Ferry-Morse Seed Company | —— |
| Red Core Chantenay | Ferry-Morse Seed Company | —— |
| Scarlet Horn | Ferry-Morse Seed Company | —— |
| Cape Market | Dr. P. W. Vorster | Africa |
| Japan 3 | Mr. O. L. Justice | Japan |
| 138572 | Division Plant Exploration and Introduction | Iran |
| 138580 | Division Plant Exploration and Introduction | Iran |
| 140389 | Division Plant Exploration and Introduction | Iran |
| 142846 | Division Plant Exploration and Introduction | Iran |
| 142852 | Division Plant Exploration and Introduction | Iran |
| 142857 | Division Plant Exploration and Introduction | Iran |
| 158697 | Division Plant Exploration and Introduction | Japan |
| 158698 | Division Plant Exploration and Introduction | Japan |
| 158699 | Division Plant Exploration and Introduction | Japan |
| 158701 | Division Plant Exploration and Introduction | Japan |
| 158702 | Division Plant Exploration and Introduction | Japan |
| 158703 | Division Plant Exploration and Introduction | Japan |

Chantenay variety. Herbarium material of most of the numbered items above has been preserved as a reference source, and is deposited in the Herbarium of the University of California, Berkeley, California.

The chromosomes of all of the forms examined were relatively small (Fig. 1), approximately equal in size, and in our sample there were no meiotic irregularities indicative of structural changes in the chromosome complement.

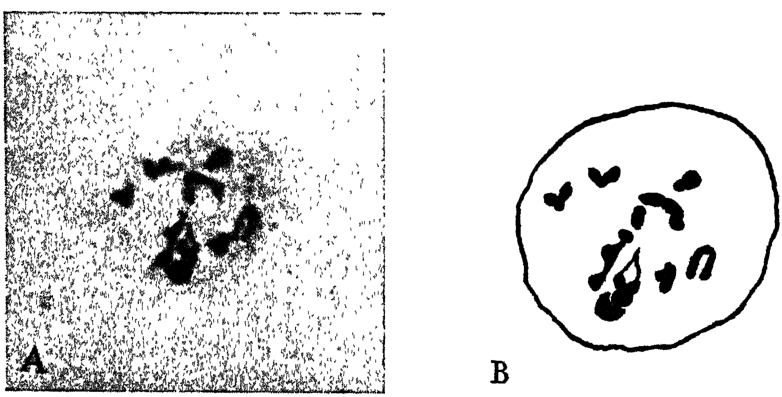


FIG. 1. Carrot chromosomes. (A) Photomicrograph of a pollen mother cell of carrot (P. I. No. 158702) showing nine pairs of chromosomes at diakinesis. (B) Explanatory diagram.

## DISCUSSION

Meldris (4) has made a preliminary survey of the chromosome numbers in the Umbelliferae. He reports 11 pairs of chromosomes in root tip cells of *Daucus carota*. Wanscher (6) in an extensive karyological survey of the family, illustrates a pollen mother cell of *D. maximus* with 11 chromosomes at metaphase II. It seems likely that these counts are erroneous. The work of Lindenbein (1), who has investigated several annual, wild forms of *D. carota* and two horticul-

tural varieties of carrot, shows very definitely that the haploid number for this species is 9 chromosomes. Additional evidence is provided by Tamamschian (5) who finds 9 chromosomes in both cultivated and wild forms of *D. carota,* by Maude (3) in her list of chromosome numbers of British Flowering Plants, and by the work reported in the present paper. Zagorodskikh (7) states that *D. maximus* hybridizes readily with *D. carota,* presumably with the production of fertile offspring. For these reasons it seems well established that *D. carota* has 9 pairs of chromosomes, and probably the same is true of *D. maximus,* although the possibility exists that there may be chromosome races within each species having 11 pairs.

In connection with the cytology of the carrot, the taxonomic studies of the cultivated and wild forms investigated by Zagorodskikh (5) are of some interest. He has divided the species into five subspecies (ecotypes). A comparison of his description with our plants indicates that all five subspecies are represented in the material at our disposal. His description of the subspecies follows with the classification of our material according to his descriptions:

*afghanicus*—Afghan carrot

Light dissection of leaf blades; greyish-green leaf coloration; strong pubescence on stems; anthocyanin in cell sap of roots; small core; short vegetative period; range — Asia, Africa and parts of Europe (Nos. 138580, 140389).

*syriacus*—Syrian carrot

Rosette leaves covered with densely set, long, soft hairs, giving dove-grey tint to plant; roots rough, drought resistant; range — Syria, Palestine, Iraq, Iran, and a considerable part of temperate Africa (No. 138572).

*cilicicus*—Sicilian carrot

Gigas rosette leaves, umbels, and other aerial portions of the plant; roots, yellow and white, due to anthocyanin, anthochlors, and small quantities of carotene and lycopenoid pigments; range — Island of Sicily (No. 142857).

*mediterraneus*—Mediterranean carrot

Characterized by strongly dissected leaf blades, with light and dark coloring; roots, orange or white, tender and succulent, orange-fleshed roots with high vitamin A content; range — Europe and America, penetrating into Asia and Africa (all cultivated varieties).

*japonicus*—Japanese carrot

Apparently the result of a cross between the Mediterranean carrot and Afghan carrot; root, blood-red, very long, up to 1m; range — Japanese Islands and coast of Japanese Sea (Japan 3, Nos. 158697, 158699).

Our data, although rather sparse, indicates that at least one item in our material can be assigned to each category. The evidence points to the conclusion that the subspecific differences cited above are not based upon differences in number or gross morphology of the chromosomes.

## SUMMARY

The chromosome number of 17 carrot items has been determined. These items comprised both wild and cultivated forms. There were nine pairs of chromosomes in all forms examined. On the basis of the present report neither polyploidy nor gross structural rearrangements of the chromosomes seem to be active in the differentiation of the multitude of forms and varieties in the species *Daucus carota* L.

## LITERATURE CITED

1. LINDENBEIN, W. Karyologische studien an *Daucus carota*. *Ber. Deut. Bot. Ges.* 50: 399–406. 1932.
2. MAGRUDER, R., *et al.* Descriptions of types of principal American varieties of orange-fleshed carrots. *U. S. D. A.* Misc. Pub. 361. 1940.
3. MAUDE, P. F. The Merton catalogue: A list of the chromosome numerals of species of British flowering plants. *New Phytol.* 38: 1–31. 1939.
4. MELDRIS, A. Chromosome numbers in Umbelliferae. *Acta Hort. Bot. Univ. Latviensis.* 5: 1–7. 1930.
5. TAMAMSCHIAN, S. Materials for the karyosystematics of the cultivated and wild growing species of the family Umbelliferae. *Bul. App. Bot. Gen. and Plant Breed.* II 2: 137–164. 1933.
6. WANSCHER, J. H. Studies on the chromosome numbers of the Umbelliferae. II. *Bot. Tidskr.* 42: 49–58. 1932.
7. ZAGORODSKIKH, P. New data on the origin and taxonomy of the cultivated carrot. *Comp. Rend. (Dokl.) Acad. Sci. USSR* 25: 520–523. 1939.

# A Gene for Male Sterility in the Muskmelon (Cucumis melo L.)[1]

By G. W. Bohn and Thomas W. Whitaker, *U. S. Department of Agriculture, La Jolla, Calif.*

The possibility of introducing heterosis with its concomitant increase in vigor, yields, and earliness into the cultural pattern of crop plants has stimulated the search for male sterile plants. For obvious reasons, male sterility, if manipulated appropriately, enables seedsmen to produce hybrid seed comparatively easily and cheaply in species that are ordinarily cross-pollinated. It is also being used in species that are ordinarily self-pollinated to reduce the cost of producing hybrid seed on a commercial scale. Most commercial varieties of muskmelons are andromonoecious, producing staminate (male) and perfect (hermaphrodite) flowers (17). The flowers are visited regularly by bees and rarely set fruits without manipulation by these insects. Rosa (14) found the amount of crossing to vary from 5 to 73 per cent in different varieties and found some evidence for selective fertilization and/or self-incompatibility in the Persian and Honeydew varieties of muskmelons. The muskmelon is therefore well adapted to manipulation in producing $F_1$ hybrid seed if a male sterile line can be used as one parent. It is the purpose of the present report to record the occurrence of a male sterile mutant in the muskmelon (*Cucumis melo* L.) and experimental observations on its hereditary nature and phenotypic effects.

## Material

Male sterile plants were discovered in the progeny of a naturally pollinated selection of a line with commercially desirable characteristics and potent resistance to powdery mildew. This line originated from a cross between the variety Hales Best and an importation of *Cucumis melo* (P. I. 79376) secured from India through the Division of Plant Introduction and Exploration of the Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture. Subsequently, it has been crossed to the Persian variety and to Powdery Mildew Resistant Cantaloupe No. 45, with a single backcross to the latter variety. Each cross has been followed by several intervening generations of selfing and selection or, occasionally, by natural pollination and selection. Its pedigree is similar to that of Powdery Mildew Resistant Cantaloupe No. 6 reported by Pryor, Whitaker, and Davis (10). Fig. 1 indicates the pertinent portion of the pedigree for the present purpose, showing the progeny in which the mutant was discovered.

## Genetic Observations

Fruits were obtained from nine plants in the progeny in which the male sterile mutant was first observed; six plants were male fertile

[1]The opportunity is taken here to thank Mr. G. A. Sanderson, Scientific Aid, for the photographs, and Mr. Sanderson and Mr. A. H. Hovley, Agent, for able assistance with the cultural and pollination work.

and three were male sterile. Four of the male fertile plants were self-pollinated, and open-pollinated fruits were obtained from the other two. The male sterile plants failed to set fruits from self-pollinated flowers but set fruits readily from pollinations with pollen from male fertile sibs (Fig. 1). The results of the progeny test of the six male

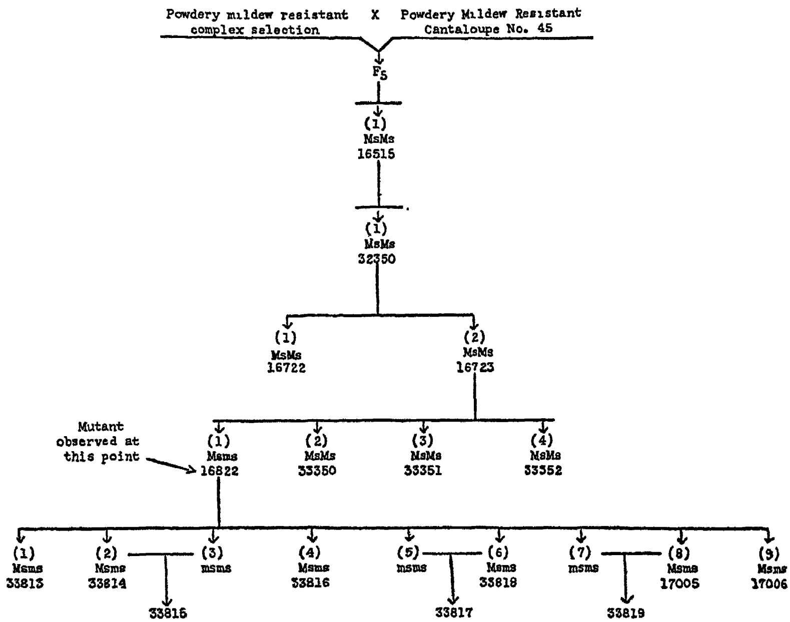


Fig. 1. Pedigree of the male sterile mutant muskmelon. Numbers in parentheses indicate individual plant selections. Numbers in the 16000 series indicate progenies from open-pollinated single plant selections; numbers in the 33000 series indicate progenies from self- and sib-pollinated selections.

fertile plants self- or open-pollinated, the three male sterile plants sib-pollinated and the parent line are recorded in Table I.

None of the six male fertile plants recorded in Table I was homozygous; all produced progeny segregating approximately three male fertile to one male sterile. In a later generation four progenies, totalling 160 plants, from self-pollinated male fertile parents failed to segregate any male sterile plants and were classified as homozygous male fertile. The progenies from two male sterile plants pollinated by male fertile sibs segregated one male fertile to one male sterile, the progeny from the third male sterile plant sibbed segregated three male fertile to one male sterile. Two plants were grown in a hill and it seems likely that a pollinated flower on the fertile plant in the hill with the male sterile plant was erroneously labeled. These data indicate that the male sterile condition is dependent upon a single recessive gene. The symbol *ms* is suggested to identify this gene; the symbol *Ms,* its normal allel.

In progeny tests of 3 sib plants of No. 16822 and of its direct ances-

TABLE I—PROGENY TESTS OF MALE STERILE PLANTS AND THEIR SIBS

| Progeny Number | Number Plants | Observed ♂ Fertile | Observed ♂ Sterile | Expected ♂ Fertile | Expected ♂ Sterile | Chi-square |
|---|---|---|---|---|---|---|
| | | | *♂ Fertile Plants Open-Pollinated* | | | |
| 16822 | 20 | 16 | 4 | 15.00 | 5.00 | 0.27 |
| 17005 | 27 | 17 | 10 | 20.25 | 6.75 | 2.09 |
| 17006 | 21 | 17 | 4 | 15.75 | 5.25 | 0.40 |
| Totals | 68 | 50 | 18 | 51.00 | 17.00 | 2.76 |
| | | | | | | 0.08 |
| | | | *♂ Fertile Plants Self-Pollinated* | | | |
| 33813 | 69 | 51 | 18 | 51.75 | 17.25 | 0.04 |
| 33814 | 68 | 51 | 17 | 51.00 | 17.00 | 0.00 |
| 33816 | 63 | 43 | 20 | 47 25 | 15.75 | 1.53 |
| 33818 | 70 | 47 | 23 | 52.50 | 17.50 | 2.30 |
| Totals | 270 | 192 | 78 | 202.50 | 67.50 | 3.87 |
| | | | | | | 2.18 |
| | | | *♂ Sterile Plants Sib-Pollinated* | | | |
| 33815 | 54 | 26 | 28 | 27.00 | 27.00 | 0.07 |
| 33817 | 61 | 49 | 12 | 30.50 | 30.50 | 22.44* |
| 33819 | 55 | 29 | 26 | 27.50 | 27.50 | 0.16 |
| Totals | 170 | 104 | 66 | 85.00 | 85.00 | 22.67* |
| | | | | | | 8.50* |

*Proportions marked by an asterisk differed significantly from the expected proportions on the hypothesis that male sterility is determined by a single recessive factor.

tors, no male steriles were recorded. These results indicate that the mutation occurred in the parent plant No. 16723–1 or that it was introduced into this line in a foreign pollen grain. The fruit from which progeny No. 16822 was obtained was open-pollinated.

## PHENOTYPIC EFFECTS

Staminate flowers from male sterile plants are normal in size and shape of all parts except the anthers (Fig. 2,B). These are small, fail to dehisce, and contain empty microspore walls (Fig. 3,B). Male fertile sibs, including heterozygotes, have normal, dehisced anthers (Fig. 2,A) that contain 88 to 96 per cent of good pollen (Fig. 3,A). Meiosis and pollen development were studied in acetocarmine and acid fuchsin lacto-phenol (8) smears. In male sterile plants meiosis is apparently normal and follows the usual steps up to the formation of tetrads; at this stage development ceases and the contents of the young pollen grains disintegrate. The units of the tetrad remain cemented together. Perfect flowers on male sterile plants are also normal in size and shape of all parts except the anthers; these are similar to the anthers of staminate flowers. There is no apparent effect on the pistil or its contents. Crosses with male fertile sibs result in normal fruits with the usual quantity of good seed.

## DISCUSSION

The list of crop plants in which male sterility has been recorded expanded rather slowly until about 1940. Since then the number has increased very rapidly and many plants with various sorts of aberrant

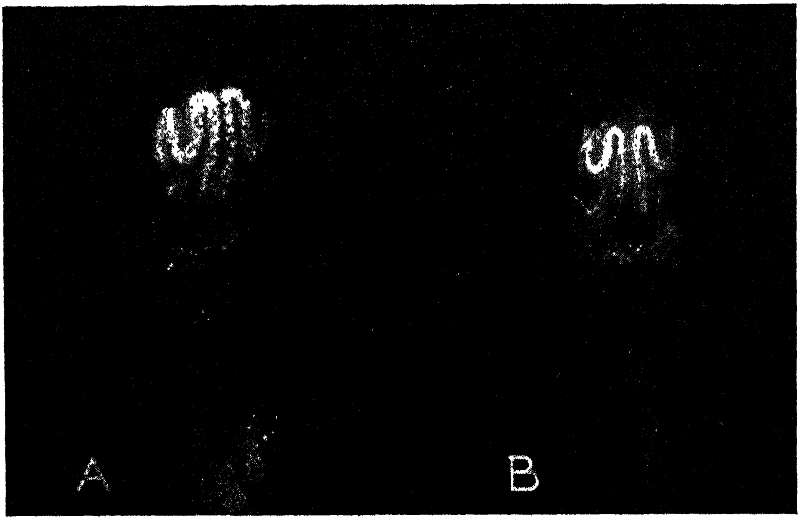


FIG. 2. Staminate flowers of the muskmelon with sepals and corollas removed to show the androecia: A, The flower from a male fertile plant with pollen on the surfaces of the dehisced anther sacs; B, The flower from a male sterile plant with non-dehisced anther sacs. ×1.5.

sexual apparatus has been reported in several crop plants. The literature has been reviewed by Allen (1), Lewis (7), Ashton (2), and Caspari (4). The reader is referred to these papers.

The modes of inheritance of male sterility have been reviewed by

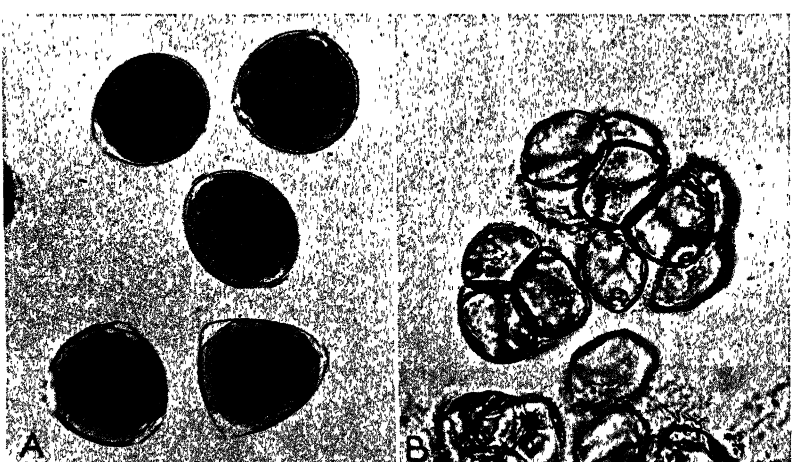


FIG. 3. Specimens from the anthers of mature muskmelon flowers: A, Normal pollen from a male fertile sib. B, Empty microspore walls from a male sterile plant. ×250.

Allen (1). Male sterility may be governed by one or a few recessive Mendelian factors, as has been reported in tomato by Lesley and Lesley (6), Rick (11), and Roever (13), in summer squash by Shifriss (16), and in winter squash by Scott and Riner (15); or by dominant factors, as reported in coleus by Rife (12). Cytoplasmic factors in addition to Mendelian factors are required to explain the observed data on certain types of male sterility, as reported in sugar beets by Owen (9) and in onion by Jones and Clarke (5). Haplontic male sterility is usually incomplete, as reported in maize by Burnham (3); diplontic sterility frequently is complete, as in the crops reported in the papers cited above.

Male sterility in the muskmelon line No. 16822 is apparently diplontic and is governed by a single recessive gene; there is little indication in the available data that cytoplasmic factors are involved.

The male sterile mutant has potential value as a tool in breeding work as well as in the production of $F_1$ hybrids for commercial culture. It can be used as the recurrent parent in a backcross program to transfer desirable genes from various sources into one line without resorting to laborious hand pollinations. Selected hybrids grown in isolation blocks with male sterile plants would produce fruits from self-pollinated flowers while the male sterile plants would produce fruits from cross-pollinated flowers. A separate isolation block would be necessary to maintain the male sterile line.

## Summary

A male sterile mutant was discovered in the muskmelon. Progeny tests indicated that male sterility was governed by a single, recessive Mendelian factor. Male sterile plants produced staminate and hermaphroditic flowers with small, indehiscent anthers containing empty pollen walls in tetrads. Meiosis was apparently normal. Heterozygous male fertile sibs produced proportions of viable pollen similar to the proportions found in unrelated male fertile muskmelons.

## Literature Cited

1. Allen, C. E. The genotype basis of sex-expression in Angiosperms. *Bot. Rev.* 6: 227–300. 1940.
2. Ashton, T. The use of heterosis in the production of agricultural and horticultural crops. *Imp. Bur. Pl. Breed. and Genetics.* Cambridge, England 30 pp. 1946.
3. Burnham, C. R. Cytogenetic studies of a case of pollen abortion in maize. *Genetics* 26: 460–468. 1941.
4. Caspari, Ernst. Cytoplasmic inheritance. *Advances in Genetics* 2: 1–66. 1948.
5. Jones, H. A., and Clarke, A. E. Inheritance of male sterility in the onion and the production of hybrid seed. *Proc. Amer. Soc. Hort. Sci.* 43: 189–194. 1943.
6. Lesley, J. W., and Lesley, M. M. Unfruitfulness in the tomato caused by male sterility. *Jour. Agr. Res.* 58: 621–630. 1939.
7. Lewis, D. Male sterility in natural populations of hermaphrodite plants. *New Phytol.* 40: 56–63. 1941.
8. Maneval, W. E. Lacto-phenol preparations. *Stain Tech.* 11: 9–11. 1936.
9. Owen, F. V. Cytoplasmically inherited male sterility in sugar beets. *Jour. Agr. Res.* 71: 423–440. 1945.

10. PRYOR, D. E., WHITAKER, T. W., and DAVIS, G. N. The development of powdery mildew resistant cantaloupes. *Proc. Amer. Soc. Hort. Sci.* 47: 347–356. 1946.
11. RICK, C. M. A survey of cytogenetic causes of unfruitfulness in the tomato. *Genetics* 30: 347–362. 1945.
12. RIFE, DAVID C. The genetics of certain common variations in coleus. *Ohio Jour. Sci.* 44: 18–24. 1944.
13. ROEVER, W. E. A promising type of male sterility for use in hybrid tomato seed production. *Science* 107: 506. 1948.
14. ROSA, J. T. Results of inbreeding melons. *Proc. Amer. Soc. Hort. Sci.* 24: 79–84. 1927.
15. SCOTT, D. H., and RINER, M. E. Inheritance of male sterility in winter squash. *Proc. Amer. Soc. Hort. Sci.* 47: 375–377. 1946.
16. SHIFRISS, OVED. Male sterilities and albino seedlings in cucurbits. *Jour. Hered.* 36: 47–51. 1945.
17. WHITAKER, T. W. Sex ratio and sex expression in the cultivated cucurbits. *Amer. Jour. Bot.* 18: 359–366. 1931.

# Some Effects of a Growth Regulator Mixture in Controlled Cross-Pollination of Lima Bean

By R. E. WESTER and PAUL C. MARTH, *Plant Industry Station, Beltsville, Md.*

EXCESSIVE dropping of blossoms and small pods of lima bean is often responsible for reduced yields, especially during periods of hot, dry weather. In breeding lima beans, this excessive drop of flowers and pods causes a low percentage of successful controlled cross-pollinations.

We (3) have reported earlier that several growth regulators failed to increase the set of lima bean pods when sprayed or dusted on flowers, pods, and leaves of the plants in the field. Since then we have used growth regulators in efforts to increase pod set by applying them directly to emasculated flowers that were to be cross-pollinated, to surfaces of the pedicels, and by scratching them into the bases of the flowers with a dissecting needle.

This paper presents the results of three methods of applying a mixture of growth regulating substances to flowers of lima bean in making controlled cross-pollinations. The work was done in a greenhouse at the Plant Industry Station at Beltsville, Maryland during the fall of 1947 and spring of 1948.

## MATERIALS AND METHODS

The number of plants and the names of varieties of large-flowered female parents used in these experiments were: four of Fordhook, four of Concentrated Fordhook, four of Fordhook 242, eight of Easy Thresh Fordhook, two of Early Market, and four of Peerless The male parents consisted of four plants each of six small-flowered nematode-resistant bush lima bean selections obtained from Dr. Howard B. Cordner of the Oklahoma Agricultural Experimental Station, and four plants of the Sieva variety.

The plants were grown in rich soil in 10-inch clay pots staged on soil in a greenhouse bench. For each treatment data were recorded on successful and unsuccessful pollinations and number of seeds found in each pod. For certain treatments the diameter of pedicels and the length and width of mature pods were also recorded.

Treated flowers were compared with control flowers of similar size, stage of development, and position on the racemes. Treated flowers and corresponding controls were generally on different racemes, but on the same plant.

The largest flower buds, on lower portion of racemes, that would open in 6 to 12 hours were selected for emasculation. Each bud was held between the thumb and forefinger of the left hand while the suture of the banner that enclosed the wings, keel, pistil, and anthers was opened with a small, narrow, flat-pointed forceps held in the right hand. The left side of the banner was held down and the wings were then straightened out with the forceps. In order to get to the keel, the left wing was pulled down to the side of the flower with

the forceps and held down with the thumb and forefinger of the left hand. The forceps was used to grasp the closest inside half of the keel near the base. By carefully unwinding upward in a counter-clockwise direction, this half of the keel was removed. The remaining part of the keel was similarly removed, thus exposing the coiled style and 10 diadelphous stamens. The stamens were pinched off with the forceps in two operations. The emasculated flower was then ready for pollination. The discharged pollen on the stigmas of the open male-parent flowers was brushed onto the stigmas of the emasculated flowers. After pollination the style was tucked back inside the wing petals and the banner was closed over the wings to retard desiccation of the pistil.

Towards the end of this series of crosses, the opened sutures of the flowers were sealed with quick-drying stationers' rubber cement as recommended by Lorz (2).

In efforts to impove the set of seed from these controlled pollinations three methods were tried for applying a mixture containing 0.8 gram indolebutyric acid and 0.2 gram parachlorophenoxyacetic acid dissolved in 3 grams warm glycerin:

1. The mixture was diluted with 96 grams water and this was sprayed onto the pistils immediately before pollination.
2. The mixture was diluted with 96 grams lanolin and this was rubbed on the pedicels of the flowers.
3. The lanolin preparation was pushed into scratches made on the base of the flower with a dissecting needle.

The controls for the three treatments respectively consisted of (a) spraying the styles with either water or a 3 per cent aqueous solution of glycerin, (b) rubbing plain lanolin on the pedicels, and (c) rubbing plain lanolin into scratches on the bases of the flowers.

Method 1 was tried during the short and cloudy days in autumn of 1947; methods 2 and 3 during lengthening days of spring in 1948.

## Results

By method 1, 258 flowers were sprayed with the growth regulating mixture and 258 with the control glycerin solution or with water. Of the "treated" flowers 4.7 per cent set pods; the glycerin control set 4.3 per cent; and the water control set 3.9 per cent. The differences were non-significant. Method 2 was similarly ineffective in improving set of pods.

Method 3 significantly increased the successful cross pollinations from 18.7 per cent for the controls, to 28.8 per cent for the "treated" flowers. The percentage of successes varied considerably among the several parental combinations (Table I), as did the relative apparent advantage (or disadvantage) of the treatment among the several combinations. Since the number of successful crosses in each combination was small, the meaning of these differences among combinations is not clear.

Treatment method 3 induced a swelling of the flower base within a few days after application and caused most of the flowers to per-

TABLE I—EFFECTS OF TREATING EMASCULATED LIMA BEAN FLOWERS WITH A GROWTH-REGULATOR MIXTURE CONTAINING 0.8 PER CENT INDOLEBUTYRIC ACID AND 0.2 PER CENT PARACHLOROPHENOXY ACETIC ACID IN LANOLIN PASTE UPON SUCCESS OF CONTROLLED CROSS-POLLINATIONS

| Parents | Number Flowers Pollinated* | Per Cent Successful Pollinations | | Number Total Seeds Obtained | | Number Seeds Per Pod | | Number Seeds Per Pollination | | Mean Diameter Pedicels (Mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Treated | Control | Treated | Control | Treated | Control | Treated | Control | Treated | Control |
| Fordhook × Sieva | 29 | 28.0 | 17.0 | 23 | 9 | 2.9 | 1.8 | 0.79 | 0.31 | 2.7 | 2.1 |
| Fordhook × Oklahoma selections | 32 | 28.0 | 9.0 | 25 | 7 | 2.8 | 2.3 | 0.78 | 0.28 | 2.8 | 1.9 |
| Fordhook 242 × Oklahoma selections | 31 | 32.0 | 23.0 | 24 | 11 | 2.4 | 1.8 | 0.77 | 0.35 | 2.8 | 2.0 |
| Concentrated Fordhook × Oklahoma selections | 28 | 36.0 | 32 0 | 22 | 21 | 2.2 | 2.3 | 0.79 | 0.75 | 3.0 | 2.1 |
| Early Market × Oklahoma selections | 27 | 30.0 | 7.0 | 16 | 3 | 2.0 | 1.3 | 0.59 | 0.11 | 3.2 | 2.4 |
| Peerless × Oklahoma selections | 28 | 36.0 | 7.0 | 23 | 2 | 2.3 | 1.0 | 0.82 | 0.07 | 2.5 | 2.0 |
| Easy Thresh Fordhook × Oklahoma selections | 34 | 23.0 | 35.0 | 20 | 25 | 2.5 | 2.1 | 0.59 | 0.74 | 3.2 | 2.0 |
| Total or mean | 219 | 28.8 | 18.7 | 153 | 76 | 2.43† | 1.95 | 0.70 | 0.35 | 2.89† | 2.04 |

*Number shown is same for treated and for controls.
†Significant increase over control.

sist for 3 to 6 days after pollination, while the controls usually dropped in 1 or 2 days. A few "treated" pods persisted until harvest without normal increase in size, and without seeds.

Not only did the growth regulator mixture increase the number of successful crosses between most parents but it also increased significantly the average number of seeds per pod and per cross between most parents. For all crosses, 63 pods from treated flowers had a total of 153 seeds, with an average of 2.43 seeds per pod; 39 pods from control flowers had a total of 76 seeds, or an average

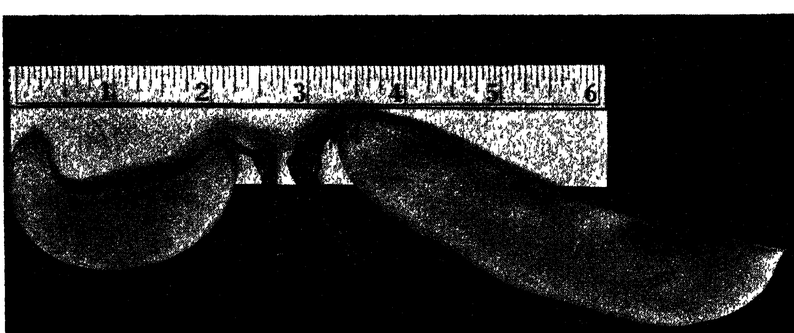


FIG. 1. Treated pod lima bean at right and check pod at left when pods had started to turn yellow and were harvested. Note that pedicel of treated pod is larger than that of the untreated pod.

of 1.95 seeds per pod (Table I). The mean difference of .48 seed per pod is significant. On the basis of pollinations attempted the treated flowers yielded twice as many seeds as the controls.

In every cross the growth regulator caused an increase in mean diameter of pedicel in comparison with its control (Table I, and Fig. 1). The mean difference for all the crosses was 0.85 mm, a highly significant value.

On the basis of the greenhouse experiments described, it appears desirable to investigate further the use of growth regulators as an aid in the controlled crossing of lima bean. The poor results generally obtained heretofore with growth regulator sprays applied to bush lima beans under field conditions (1,3) to prevent flower shedding may have been due to lack of penetration of the materials into the plant. In the present work a light scratching of the base of the flower with a dissecting needle apparently was a great aid to penetration of the reagents, which in turn brought about increase in flower setting and number of seeds produced.

## Summary

An aqueous solution containing 0.8 per cent indolebutyric acid, 0.2 per cent parachlorophenoxyacetic acid, and 3 per cent glycerine when sprayed on emasculated lima bean flowers just before pollination caused no significant difference in percentage of successful crosses obtained. Likewise, when a growth-regulator mixture of equal concentration in lanolin paste was rubbed on the base of the flower there was no difference in the number of successful crosses.

When the base of the lima bean flower was scratched with a dissecting needle and the growth-regulator mixture in lanolin paste was then pressed into this area, the growth regulator entered the flower and the pedicel and affected their development. The majority of abscised treated flowers remained attached 2 to 3 days longer than abscised untreated flowers. Under the conditions of these experiments, the growth regulator treatment caused a significant increase in pedicel diameter of mature pods with an increase in the number of successful crosses from 18.7 per cent to 28.8 per cent. It also caused a significant increase in the average number of seed per pod, from 1.95 to 2.43, and doubled the number of seeds per pollination.

## Literature Cited

1. Clore, W. J. The effect of alpha-napthaleneacetic acid on certain varieties of lima beans. *Proc. Amer. Soc. Hort. Sci.* 51:475–478. 1948.
2. Lorz, A. P. Rubber cement as an aid in snap and lima bean crossing technique. Mimeographed report, Gainesville, Fla., August, 1948.
3. Wester, R. E., and Marth, Paul C. Effect of some growth regulators on yield of bush lima beans. *Proc. Amer. Soc. Hort. Sci.* 49:315–319. 1947.

# Factors Influencing Breakage Resistance in Watermelons

By C. F. Andrus, *U. S. Department of Agriculture, Charleston, S. C.*

Breakage of watermelons in shipment has concerned growers, shippers, and transportation agencies perhaps more than any other problem connected with this important crop. Watermelon breeders, too, must consider resistance to breakage one of their primary goals. Considering the acknowledged importance of breakage resistance, it is remarkable that so little is known of the breakage characteristics of our most familiar varieties.

The Regional Vegetable Breeding Laboratory of the United States Department of Agriculture has had this problem under consideration for several years, but up to 1948 our only data consisted of penetrometer readings which measured the hardness of the rind, by a method similar to that used by Kenny and Porter (1). Melons were considered either tough or tender, with the implication that toughness of the rind determines resistance to breakage.

In the following report of the 1948 tests we outline a procedure that we believe will give watermelon breeders the information they need on resistance to breakage. Although the data are meager, they point to a seldom-recognized fact, namely, that the greater part of the breaking strength of a watermelon lies in the character of the flesh.

## Materials and Methods

A few of the melons used came from commercial fields at Hampton, South Carolina, and a few also from Laurinburg, North Carolina; most of them, however, were from the Regional Vegetable Breeding Laboratory plots at Charleston, South Carolina. Some were held at 40 degrees F for various periods and some came directly from the field. The matter of getting enough melons to test is the biggest problem we have to contend with. It is necessary that the melons be perfectly sound and of marketable size. No melons under 15 pounds were used in breakage tests; however, most of them were in the 15- to 25-pound class, which is smaller than preferred by most shippers.

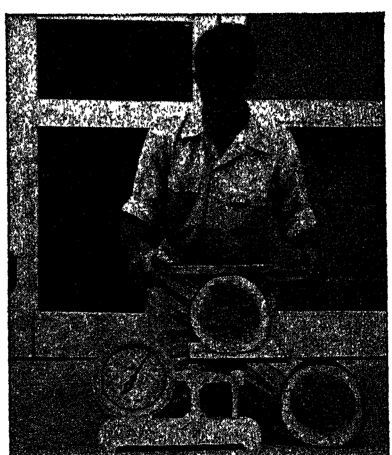

Fig. 1. Method of measuring the breaking strength of watermelon flesh and rind.

All breakage tests were made by cutting 3-inch slices from the midsection or the point of greatest diameter. A double-bladed knife was used until it became

apparent that the excessive pressure required to force the double blade through the melon was causing the flesh to crack. Thenceforth the double blade (set 3 inches apart) was used to mark the surface and the slice was removed with a single blade. The slice was placed on the platform of a dial-reading scale (Fig. 1) and pressure applied from above until the flesh was heard to crack. The highest point registered on the dial was entered as the breaking strength of the flesh. The edible flesh then was separated from the ring with a narrow-bladed knife. Pressure again applied on the ring gave the breaking point of the rind.

The importance of separating the flesh from the rind was not realized when the tests were begun, hence the breakage strength of the rind only is missing from part of the data.

Resistance to puncture was measured with a simple spring-operated instrument that registers the relative pressure required to force a brass needle of known diameter through the skin. Similar instruments, or penetrometers, such as described by Magness (2), have been used to measure the tenderness of peas and sweetcorn. Measurements also were made on each melon to show weight, shape, diameter at mid-section, thickness of the rind (to pink), and degree of ripeness, all with a view to possible correlation with breaking strength; but these data are not presented herewith. About 250 melons were sampled.

TABLE I—BREAKING STRENGTH OF WATERMELONS

| Variety | Varietal Characteristic | No. of Melons | Average Breaking Strength (Lbs) | | |
|---|---|---|---|---|---|
| | | | Flesh | Rind | Flesh + Rind |
| W 290 | Hard rind; hollow heart tendency | | | | |
| | 1. Solid flesh | 3 | 76.7* | 23.0* | 99.7* |
| | 2. Slightly hollow heart | 6 | 30.7 | 21.3 | 52.0 |
| W 407 | 3. Solid flesh | 42 | 40.5 | 17.6 | 58.1 |
| | 4. Slightly hollow heart | 6 | 23.5 | 23.3 | 46.8 |
| W 407 | 5. Under 8 inch diameter | 31 | 38.7 | 17.1 | 55.8 |
| | 6. 8 inches or more | 17 | 38.4 | 20.6 | 59.0 |
| WC 56-A | Hard rind; no hollow heart | | | | |
| | 7. Under 8 inches diameter | 13 | 44.8 | — | — |
| | 8. 8 inches or more | 10 | 53.5 | — | — |
| No. 47-3 | 9. Under 25 pounds | 18 | 59.2 | — | — |
| | 10. 25 pounds or more | 12 | 58.4 | — | — |
| W 407 | Hard rind; hollow heart tendency | | | | |
| | 11. Thin rind | 27 | 39.6 | 16.9 | 56.5 |
| | 12. Thick rind (over ⅞ inch) | 21 | 37.3 | 20.2 | 57.5 |
| W 407 | 13. Underripe | 16 | 40.2 | 17.0 | 57.2 |
| | 14. Normal ripe | 29 | 39.7 | 18.1 | 57.8 |
| No. 46-40 | Hard rind; no hollow heart | | | | |
| | 15. Random | 23 | 63.2 | 15.0 | 78.2 |
| Dixie Queen | Hard rind | | | | |
| Wilt Resistant | 16. Random | 6 | 47.5 | — | — |
| Miles | Soft rind | | | | |
| | 17. Random | 2 | 40.5 | — | — |
| Garrison | 18. Random | 2 | 38.0 | 6.0 | 44.0 |

*Pressure in pounds sustained by a 3-inch cross-section.

## ANALYSIS OF TABLE I

A 3-inch slice of one of the melons in sample 1 sustained a weight of eighty pounds before the flesh broke; a pressure of over 20 pounds was required to break the rind. This showed remarkable and entirely unpredicted strength in the flesh. Sample 15 closely approaches sample 1 in strength of flesh, and all samples except those with hollow

heart support the hypothesis that the greater portion of the breakage strength of a melon lies in the flesh.

Weakness in melons with hollow heart (samples 2 and 4), compared with normal or solid-flesh specimens, is due to the fact that the flesh is already partly broken. A tendency to hollow heart in a variety or breeding line, therefore, should be looked upon with great disfavor, for it is probable that melons with hollow heart will be the first to break during shipment.

Samples 5 and 6 indicate that diameter of the melon has little or no effect on breaking strength. From a mathematical viewpoint one would expect a melon of small diameter to sustain a greater weight than one of larger diameter, other factors being equal. Samples 7 and 8 indicate an opposite tendency, but this we have reason to believe is due to heterogeneity of the samples with respect to size and breaking strength. WC56–A is believed to contain two types, one with inherently weak flesh and one with inherently stronger flesh. In samples 5 to 8 also the effects of diameter may be confused with the effects of maturity, that is, a melon is believed to increase in strength with maturity up to a certain point.

In samples 9 and 10 size also seems to have no significant relation to breaking strength, but here too the effect may have been due to a weight, diameter, and maturity complex. These two samples are from a very tough Watson-type melon in which the specimens were mostly underripe. Theoretically a large melon could be so weak structurally that it would break of its own weight.

Samples 11 and 12 indicate that thickness of the rind has little effect on the over-all breaking strength, at least in this particular variety.

Samples 13 and 14 show no significant difference in breaking strength due to the degree of ripeness. We would expect the strength of the flesh to decline and the strength of the rind to increase gradually up to full maturity. Perhaps the effect would show more clearly if overripe samples were included. There were no overripe specimens in the material tested.

Up to this point the samples discussed all have had a hard or tough rind, and we believe there is no significant difference shown in the breaking strength of hard rinds (independent of flesh), with the possible exception of sample 15. This variety has a rather thin hard rind that may be slightly brittle; yet it has remarkably strong flesh, and, in the absence of any tendency to hollow heart, should make an excellent shipping melon.

Sample 18 suggests what one may expect of the soft-rind melons. Although the tender or soft rinds may prove to be incapable alone of sustaining any great pressure, it would still seem possible to have one with especially well-constructed flesh that would stand shipment in spite of its external tenderness.

## Discussion

All the tests above were made on cut sections. The breaking strength of the uncut melons should prove to be greater, but should vary relatively only in respect to shape. Even the factor of shape may prove to

be relatively unimportant. Irrespective of these considerations we believe that the method outlined will give us the information we need and that it is a most practical aid in studying the problem of breakage in shipment.

We believe that breakage tests should be based on not less than 50 melons and perhaps as many as 200 melons of each variety. There are approximately 15 important varieties now being shipped from the South, and several of these are known to have distinct strains. This would add up to several carloads of watermelons. The method described can be followed anywhere, and the resulting data should be comparable, subject only to environmental effects which remain to be investigated.

## Summary

Direct measurements of the breakage strength of cut sections of watermelons indicate that:

The greater part of resistance to breakage is due to characteristics of the flesh.

Hollow heart is the factor most conducive to breakage, although other flesh characteristics, not easily defined, are also important.

Toughness of the rind is second in importance.

Diameter of the melon and thickness of the rind are relatively minor factors in respect to breakage.

## Literature Cited

1. Kenny, Ivan J., and Porter, D. R. Relative rind toughness among watermelon varieties. *Proc. Amer. Soc. Hort. Sci.* 38: 537–540. 1941.
2. Magness, J. R. An improved type of pressure tester for the determination of fruit maturity. *U. S. D. A. Cir.* 350: 1–8. 1925.

# Tomato Fruit Set and Development with Particular Reference to Premature Softening Following Synthetic Hormone Treatment[1]

By FREEMAN S. HOWLETT, *Ohio Agricultural Experiment Station, Wooster, Ohio*

SUBSTANTIAL evidence has already been offered that the treatment of greenhouse tomato flowers with synthetic hormones produces outstanding increases in yield both experimentally and in commercial use. Applied to the flowers of the spring crop bedded during the cloudy, short days of winter the increase in total yield has amounted to as much as 136 per cent (unpublished, Columbia Greenhouse Company tests made spring crop 1946). It was necessary, however, to treat plants during the whole season to obtain yields of this magnitude.

Despite this improvement in yield, treatment of greenhouse tomato flowers has been discontinued in Ohio and the Experiment Station is not at present recommending further applications. The nature of the fruits produced, as expressed in their behavior after removal from the plant, has unfortunately resulted in abandonment of the practice by Ohio growers, who in 1946 treated practically all tomatoes grown in the spring crop, several hundred gallons of solution containing the synthetic hormones having been utilized for this purpose. Despite this present severe setback, and because it is hoped that it may prove only temporary, the writer is continuing the investigations in order to study particularly these effects of chemical treatment upon the nature of the fruits produced. This paper, presenting data taken from the 1948 spring crop is a partial report of such a project.

The detrimental behavior of the fruits, to which reference has already been made, may be described as a premature softening, not at once, nor necessarily of the whole fruit but usually involving the whole. It does not occur until after the fruits have been removed from the plant. In advanced cases the fruits may take on a somewhat glassy and finally a water-soaked appearance. In addition, the growers have frequently pointed out what they call a blister-like area appearing on a small portion of the surface, a characteristic not necessarily present in all softened fruits. The general condition is recognized by the reduced resistance to the thumb when examining the firmness of different portions of the fruit.

Naturally the handling, grading, packing, and transportation of the fruits (together with the pernicious "pinching" by the prospective customer) accentuates the softening tendency. The fact that a majority of the fruits may not exhibit this condition does not minimize the problem since even a small proportion of substandard fruits in such a high cost crop is a sufficient hazard to prevent adoption of the practice. Marked improvement in yield cannot be counterbalanced by loss of market.

It is interesting to note that several years elapsed after the first lim-

[1]Approved for publication by the Ohio Agricultural Experiment Station as Journal article No. J32-48.

ited commercial use in 1940 before the premature softening disturbed the growers and came to the attention of the writer. Actually it was not until the spring of 1946 when practically the entire crop was treated that the evidence became alarming. The delay can probably be explained by the fact that up to that time treated and untreated fruits were mixed in grading and handling and it was, therefore, impossible that treatment would be definitely designated as the primary cause of the observed condition. The fact that softening does not usually occur until 1 to 2 days from picking also tended to mask the evidence.

From the time when the experimental work was initiated in 1938, the writer had noted that the gelatinous pulp of many treated fruits developed a greenish tinge which, as it did not appear to affect the fruit in quality, did not result in Ohio in any resistance to flower treatment. This condition changed with time often disappearing as the season advanced. Different treatments resulted in partial development of this pulp; others discouraged it entirely. In certain cases the fruits appeared puffy while in others the walls of the locules were contiguous, with no pulp or seedcoats present. In fact, it became evident quite early that different chemicals produced different effects upon the amount, color, and distribution of the pulp, upon the number and size of seedcoats, thickness of the carpel walls and other characteristics. These variations occurred in response to the concentration and particular combination of chemicals, in response to the season, the cluster treated, the flowers involved and the time elapsing after anthesis before treatment was carried out. These variations might have been considered and modified by means of the chemical formula employed had it not been for the fact of premature softening. It is with this effect that this paper is primarily concerned rather than with the increase in yield which is still known to be exceedingly gratifying.

The 200 tomato plants used in this work (28 to 29 plants to a treatment) were of the Globe (strain A) variety. The seed was sown in flats November 7, 1947, and the plants transplanted on November 18 to 4-inch pots and again on January 2, 1948, to 12-inch pots, where they remained until discarded. The soil mixture consisted of 4 parts of Wooster silt loam soil, 1 part of well-rotted manure to which in addition a nitrogen-carrying fertilizer, superphosphate and potassium sulfate were added. Superphosphate (14 grams 20 per cent) and potassium chloride (14 grams) were applied to each pot as a side-dressing on March 9 and a manure mulch was added to the pots on April 16. The plants were trained to one stem and headed back after flowering of the fourth cluster. The hormone treatments were applied to both the pollinated and emasculated flowers. Pollination was effected by means of an electric vibrating device. Table I indicates the date of treatment of each of the four clusters both for the pollinated and the emasculated flowers.

A flower was treated only once by means of an atomizer containing the liquid. Twenty-six applications were made to the pollinated flowers and 36 to the emasculated during the period February 3 to March 19.

The fruits were harvested when turning pink, were examined at once for softness and then placed in a basement storage at a tempera-

TABLE I—PERIOD OF TREATMENT OF POLLINATED AND EMASCULATED FLOWERS

| Cluster No. | Date of Treatments | |
|---|---|---|
| | Pollinated Flowers | Emasculated Flowers |
| 1 | Feb 13 to Mar 1 | Feb 3 to Feb 24 |
| 2 | Feb 11 to Mar 20 | Feb 9 to Mar 1 |
| 3 | Feb 20 to Mar 15 | Feb 16 to Mar 10 |
| 4 | Feb 25 to Mar 19 | Feb 24 to Mar 12 |

ture ranging from 60 to 70 degrees F from which they were removed for examination at regular intervals up to 14 days thereafter. The fruits considered soft (only one side or portion was sufficient to place them in this category) at each examination period were then cut transversely and examined internally for color and distribution of the gelatinous pulp together with the relation of any soft portion to any noticeable flesh characteristic.

The chemicals utilized[2] in this work and their concentration were as follows:

1. Indolebutyric acid (0.2 per cent) and beta-naphthoxyacetic acid (50 parts per million) in water solution (IB plus BNOA).
2. Beta-naphthoxyacetic acid (50 parts per million) in water solution (BNOA).
3. Ortho-chlorophenoxypropionic acid (50 parts per million) in water solution (OCPPA).
4. Para-chlorophenoxypropionic acid (50 parts per million) in water solution (PCPPA).

## PRESENTATION OF THE DATA

*Average Total Yield Per Plant:*—The average total yield per plant for all treatments are shown graphically in Fig. 1. It should be noted that all treatments resulted in a pronounced increase in yield of the first three clusters. In the fourth, only para-chlorophenoxypropionic acid compound increased the yield over the untreated plants. As a matter of interest it should also be noted that the emasculated and treated flowers produced fully as large a yield as the pollinated and treated plants.

*Average Weight per Fruit:*—The data pertaining to average weight per fruit are presented graphically in Fig. 2. All treatments throughout the four clusters produced larger fruits than those obtained from the untreated plants.

*Percentage of Flowers Setting Fruit:*—All treatments resulted in outstanding improvement in set in the first two clusters, increases ranging from 60 to 115 per cent. In the third cluster, all but the flowers emasculated and treated with beta-naphthoxyacetic acid showed an improvement in set while in the fourth cluster only the flowers emas-

[2] Part of the chemicals used for this work were supplied by the Dow Chemical Company.

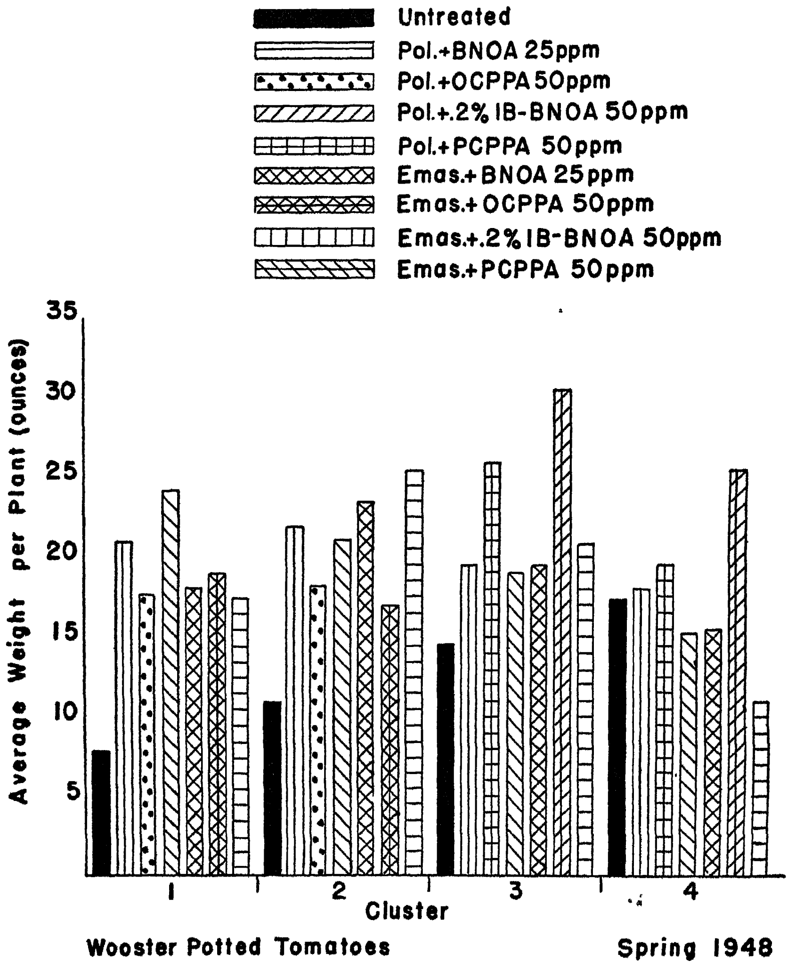


FIG. 1. Average weight of fruits per cluster from flowers treated and untreated with synthetic hormones.

culated and treated with para-chlorophenoxypropionic acid equalled or exceeded the set of untreated flowers.

*Relation of Treatment to Premature Softening:*—The rate of softening of fruits from treated and untreated flowers is graphically compared, Figs. 3 to 6. The data indicate that fruits resulting from emasculated treated flowers did soften more rapidly than those from untreated flowers. This result was noticeable throughout four clusters. On the other hand, fruits from pollinated treated flowers were (with one exception) as firm or firmer than the untreated fruits through the third cluster. In fact in the first cluster, fruits resulting from treatment

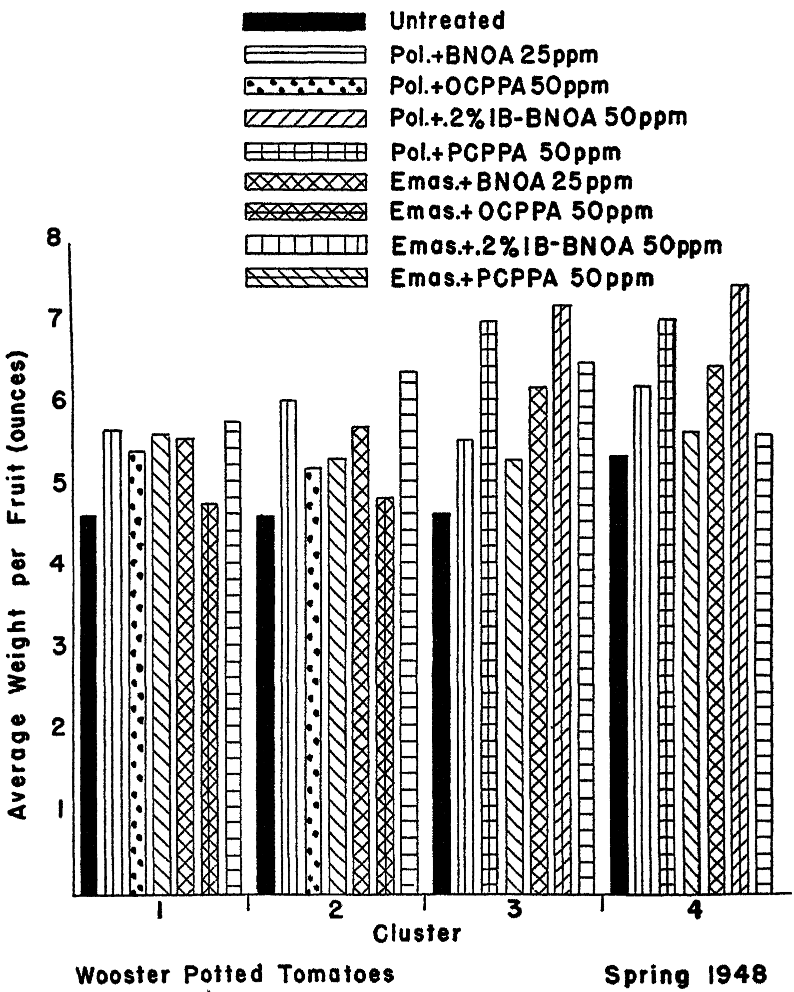


FIG. 2. Average weight per fruit from flowers treated and untreated with synthetic hormones.

with ortho-chlorophenoxypropionic acid actually softened less rapidly than the untreated fruits. In the second cluster, pollinated treated fruits softened less rapidly after a few days of storage. The fruits from pollinated flowers treated with para-chlorophenoxypropionic acid in the third cluster did, however, soften more rapidly than the untreated fruits. In the fourth cluster all fruits from pollinated treated flowers softened more rapidly than those from untreated ones. The progressive reaction to treatment, occurring as the season advanced and becoming more evident from cluster to cluster was an interesting phenomenon.

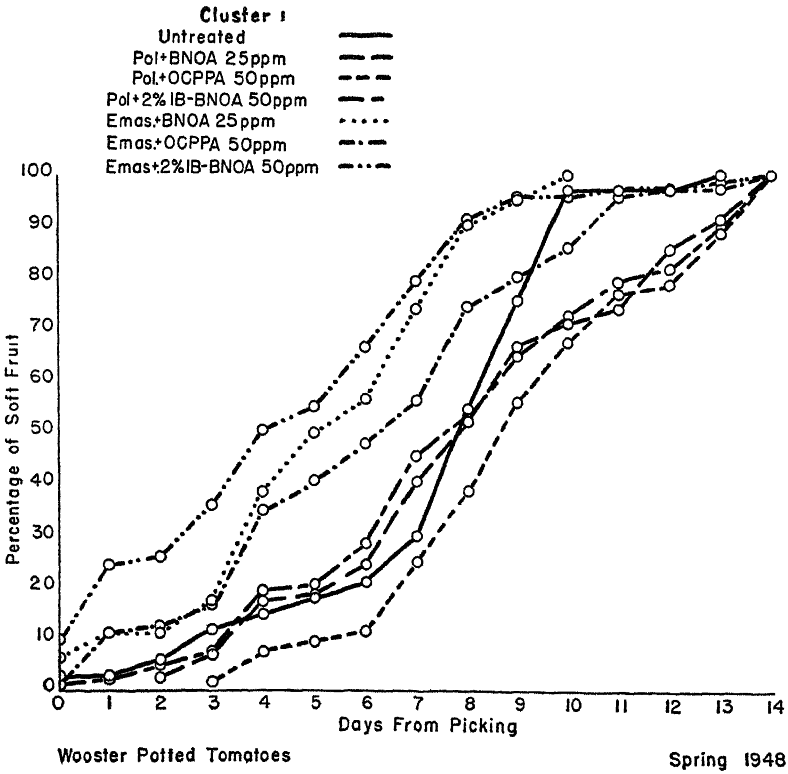


FIG. 3. Rate of softening resulting from treatment (cluster 1).

Differences in the softening of fruits produced by the different synthetic hormones were also evident. The combination of indolebutyric acid and beta-naphthoxyacetic acid produced the most rapidly softening fruits from emasculated flowers. Only beta-naphthoxyacetic acid alone produced a greater degree of softening in the fourth cluster. Ortho-chlorophenoxypropionic acid produced the firmest fruit in the first cluster, even firmer than the untreated fruits.

*Effect of Treatment upon Internal Fruit Characteristics:*—The data concerned with internal fruit characteristics are presented in Table II. The percentage of fruits completely filled with gelatinous pulp varied with the different treatments. Both the pollinated and emasculated flowers resulting from treatment with indolebutyric acid in combination with beta-naphthoxyacetic acid and from beta-naphthoxyacetic acid alone exhibited more pulp development with the exception of the first cluster than the fruits from untreated flowers. These treatments have in general resulted in well-filled locules. On the other hand, para-chlorophenoxypropionic acid applied to pollinated and emasculated flowers resulted generally in rather poor pulp development.

TABLE II—GELATINOUS PULP AND LOCULE CHARACTERISTICS OF TREATED AND UNTREATED FRUIT

| Treatment | No. of Locules | Percentage of Fruits | | Percentage of Locules | | | | | Condition on Soft Portion of Fruits | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Filled | No Pulp or Partially Filled With Pulp | Pulp Green | Pulp Medium Green | Pulp Red | Filled Completely With Pulp | No Pulp or Partially Filled | Pulp Green or Medium Green | Pulp Red | Locules Completely Filled | Locules Partially Filled |
| | | | | | | *Cluster 1* | | | | | | |
| Untreated........ | 188 | 78.8 | 21.2 | 0.0 | 21.3 | 78.7 | 95.7 | 4.3 | 24.2 | 75.8 | 97.0 | 30.0 |
| Pollinated | | | | | | | | | | | | |
| 21B & BNOA... | 580 | 65.8 | 34.2 | 1.2 | 29.0 | 69.8 | 87.4 | 12.6 | 31.7 | 68.3 | 84.8 | 15.2 |
| BNOA 25...... | 456 | 75.4 | 24.6 | 4.8 | 36.4 | 58.8 | 90.8 | 9.2 | 47.8 | 52.2 | 82.6 | 17.4 |
| OCPPA 50..... | 366 | 88.2 | 11.8 | 0.0 | 37.7 | 62.3 | 97.8 | 2.2 | 37.3 | 62.7 | 98.0 | 2.0 |
| Emasculated | | | | | | | | | | | | |
| 21B & BNOA 50 | 475 | 58.1 | 31.9 | 4.2 | 25.7 | 70.1 | 86.5 | 13.5 | 31.9 | 68.1 | 79.7 | 20.3 |
| BNOA 25...... | 429 | 88.7 | 11.3 | 9.8 | 58.5 | 31.7 | 95.8 | 4.2 | 74.2 | 25.8 | 95.2 | 4.8 |
| OCPPA 50...... | 454 | 98.6 | 1.4 | 7.7 | 58.4 | 33.9 | 99.6 | 0.4 | 68.6 | 31.4 | 98.6 | 1.4 |
| | | | | | | *Cluster 2* | | | | | | |
| Untreated........ | 153 | 50.0 | 50.0 | 0.0 | 22.2 | 77.8 | 87.6 | 12.4 | 20.8 | 79.2 | 75.0 | 25.0 |
| Pollinated........ | | | | | | | | | | | | |
| 21B & BNOA 50 | 506 | 60.0 | 40.0 | 1.2 | 37.9 | 60.9 | 85.2 | 14.8 | 37.3 | 62.7 | 74.7 | 25.3 |
| BNOA 25 ...... | 404 | 79.4 | 20.6 | 8.9 | 28.2 | 62.9 | 90.1 | 9.9 | 36.5 | 63.5 | 84.1 | 15.9 |
| OCPPA 50..... | 432 | 71.0 | 29.0 | 3.0 | 49.8 | 47.2 | 89.1 | 10.9 | 59.7 | 40.3 | 85.5 | 14.5 |
| Emasculated | | | | | | | | | | | | |
| 21B & BNOA 50 | 545 | 65.4 | 34.6 | 13.4 | 61.8 | 24.8 | 84.4 | 15.6 | 72.0 | 28.0 | 82.1 | 18.0 |
| BNOA 25...... | 522 | 71.6 | 28.4 | 15.9 | 58.2 | 25.9 | 80.7 | 19.3 | 78.4 | 21.6 | 75.7 | 24.3 |
| OCPPA 50..... | 426 | 84.6 | 15.4 | 18.1 | 64.8 | 17.1 | 93.0 | 7.0 | 89.2 | 10.8 | 93.9 | 6.1 |
| | | | | | | *Cluster 3* | | | | | | |
| Untreated........ | 239 | 52.3 | 47.7 | 0.0 | 10.5 | 89.5 | 82.0 | 18.0 | 20.5 | 79.5 | 65.9 | 34.1 |
| Pollinated........ | | | | | | | | | | | | |
| 21B & BNOA 50 | 464 | 59.2 | 40.9 | 6.0 | 35.8 | 58.2 | 78.2 | 21.8 | 46.5 | 53.5 | 71.8 | 28.2 |
| BNOA 25....... | 439 | 47.8 | 52.2 | 4.8 | 60.4 | 34.8 | 78.4 | 21.6 | 66.7 | 33.3 | 62.3 | 37.7 |
| PCPPA 50..... | 436 | 8.2 | 91.8 | 8.5 | 50.9 | 40.6 | 36.5 | 69.5 | 57.4 | 42.6 | 23.0 | 77.0 |
| Emasculated | | | | | | | | | | | | |
| 21B & BNOA 50 | 426 | 72.6 | 27.4 | 16.2 | 55.6 | 28.2 | 85.0 | 15.0 | 75.8 | 24.2 | 82.3 | 17.7 |
| BNOA 25...... | 353 | 69.1 | 30.9 | 13.9 | 76.0 | 16.1 | 81.3 | 18.7 | 83.6 | 16.4 | 70.9 | 29.1 |
| PCPPA 50..... | 507 | 35.7 | 64.3 | 0.0 | 80.0 | 20.0 | 61.3 | 38.7 | 72.9 | 27.1 | 41.4 | 58.6 |
| | | | | | | *Cluster 4* | | | | | | |
| Untreated........ | 373 | 43.3 | 56.7 | 0.0 | 11.5 | 88.5 | 80.2 | 19.8 | 6.6 | 93.3 | 75.0 | 25.0 |
| Pollinated........ | | | | | | | | | | | | |
| 21B & BNOA 50 | 360 | 56.6 | 43.4 | 9.2 | 59.2 | 31.7 | 76.1 | 23.9 | 64.2 | 35.8 | 69.8 | 30.2 |
| BNOA 25....... | 452 | 63.8 | 36.2 | 15.5 | 42.5 | 42.0 | 87.0 | 13.0 | 59.4 | 40.6 | 84.1 | 15.9 |
| PCPPA 50..... | 364 | 12.2 | 87.8 | 0.0 | 61.8 | 38.2 | 44.2 | 55.8 | 57.1 | 42.9 | 28.6 | 71.4 |
| Emasculated | | | | | | | | | | | | |
| 21B & BNOA 50 | 215 | 82.4 | 17.6 | 24.2 | 66.5 | 9.3 | 96.7 | 3.3 | 91.2 | 8.8 | 97.1 | 2.9 |
| BNOA 25...... | 315 | 66.7 | 33.3 | 22.5 | 72.1 | 5.4 | 89.7 | 10.3 | 93.8 | 6.2 | 87.5 | 12.5 |
| PCPPA 50..... | 495 | 70.0 | 30.0 | 12.7 | 81.8 | 5.5 | 87.5 | 12.5 | 94.3 | 5.7 | 87.1 | 12.9 |

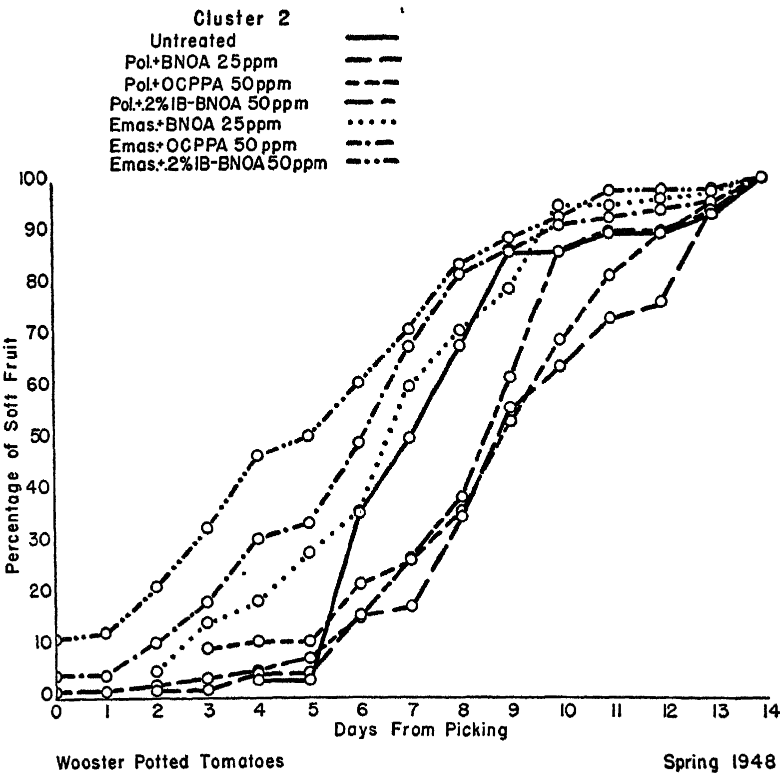


FIG. 4. Rate of softening resulting from treatment (cluster 2).

Although pulp development was of interest, its color was of considerably more importance to this investigation. In general the fruits from untreated flowers, while showing no definitely green pulp, did develop a medium green to green-tinged condition in 10 to 20 per cent of the locules. Green pulp was visible, however, in both the pollinated treated and emasculated fruits. There was also a greatly increased percentage of medium green to green-tinged pulp. Fruits from treated flowers were decidedly at a disadvantage in this respect compared with fruits from untreated flowers. Furthermore, this divergence between the treated and untreated fruits became greater as the season advanced. This result was surprising, being contrary to general expectation.

Evidence in respect to pulp color and locule content in the particular area of softening is shown in Table II. Comparison of the data shows, however, no increase of this condition in a localized area, since the data showing locule content and pulp color for the fruits as a whole are similar. From the beginning, the pulp coloration of both the pollinated-treated and emasculated fruits was greener than that of the untreated — a condition which increased progressively up to the fourth

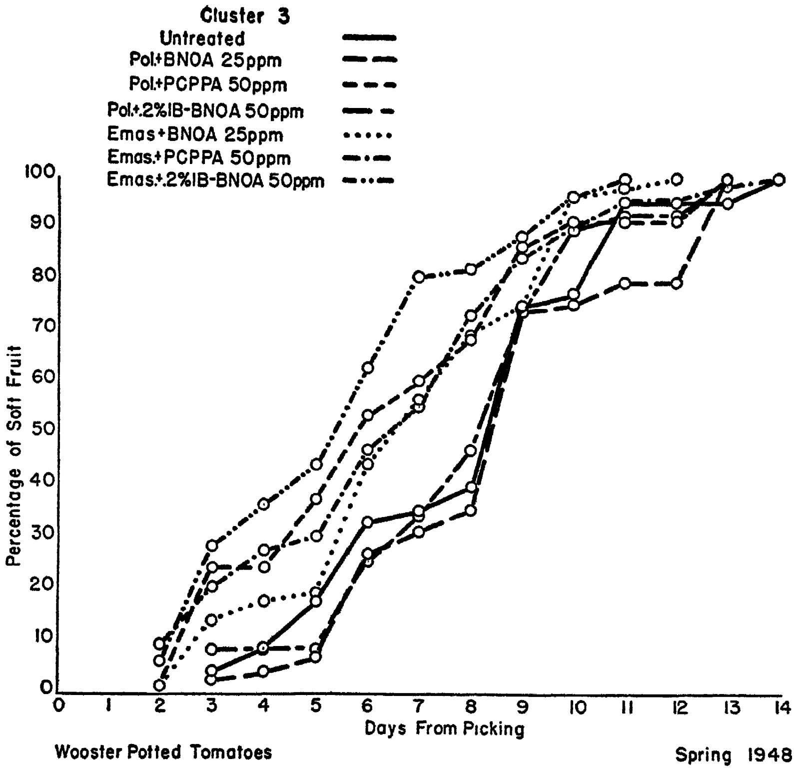


FIG. 5. Rate of softening resulting from treatment (cluster 3).

cluster, at which time only 36 to 43 per cent of the pollinated-treated fruits showed normal red coloration, and only 6 to 9 per cent of the emasculated, as compared with 93 per cent of the untreated fruits showing normal redness.

Furthermore, differences between the treated and untreated fruits in regard to the filling of the locules were similar in the localized area of softening to the condition evident in the fruits as a whole.

## Discussion

Thus the data here presented show clearly that in these tests, premature softening resulted from treatment of tomato flowers with synthetic hormones. The emasculated-treated fruits showed the most rapid rate of softening and were distinguished by the fact that this condition occurred in the first four clusters. The pollinated-treated fruits, on the other hand, did not, with but one exception, soften faster than the untreated fruits *until* the fourth cluster. The comparison of these data is indicated in Table III showing the number of days which elapsed

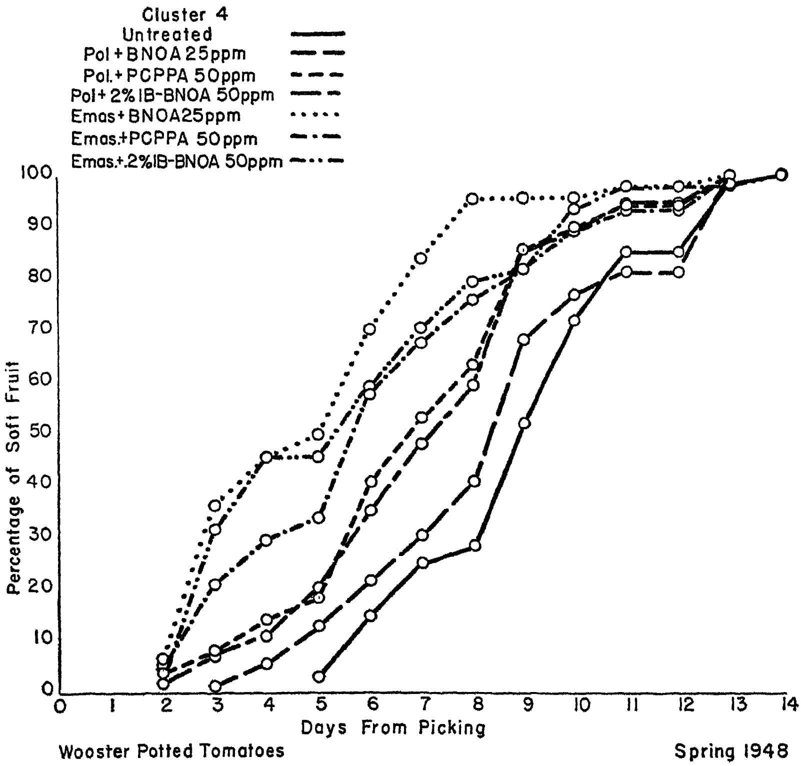


FIG. 6. Rate of softening resulting from treatment (cluster 4).

TABLE III—NUMBER OF DAYS REQUIRED FOR 25, 50, AND 75 PER CENT OF FRUITS TO SOFTEN

| Treatment | Days Elapsing Before the Following Percentage of Softening Developed | | | |
|---|---|---|---|---|
| | 25 | 50 | 75 | 100 |
| | *Cluster 1* | | | |
| Untreated | 6.5 | 8.0 | 9.0 | 13 |
| Pollinated plus IB-BNOA | 5.5 | 7.5 | 10.5 | 14 |
| Emasculated plus IB-BNOA | 1.5 | 4.0 | 6.5 | 14 |
| | *Cluster 2* | | | |
| Untreated | 6.0 | 7.0 | 8.5 | 14 |
| Pollinated plus IB-BNOA | 7.0 | 8 5 | 9.5 | 14 |
| Emasculated plus IB-BNOA | 2.5 | 5.0 | 7.5 | 14 |
| | *Cluster 3* | | | |
| Untreated | 5.5 | 8.0 | 9.0 | 14 |
| Pollinated plus IB-BNOA | 6.0 | 8.0 | 9 0 | 13 |
| Emasculated plus IB-BNOA | 3.0 | 5.5 | 6.5 | 11 |
| | *Cluster 4* | | | |
| Untreated | 7.0 | 9.0 | 10.0 | 14 |
| Pollinated plus IB-BNOA | 7.0 | 7.0 | 8.5 | 13 |
| Emasculated plus IB-BNOA | 3.0 | 5.0 | 7.5 | 14 |

before softening occurred in 25, 50, and 75 per cent of the fruits undergoing the different experimental treatments. The material considered in this case was the combination of indolebutyric acid with beta-naphthoxyacetic acid.

The data indicate that 25 per cent of the emasculated-treated fruits softened in less than half the time required to soften untreated fruits. The 50 per cent stage was reached in slightly more than half the time of untreated fruits. It is interesting to note that the difference between these two lots decreased as it approached the stage of 75 per cent softening. In fact, around the eighth and ninth days the untreated fruits showed a pronounced acceleration in the rate of softening. It is still more interesting to note that for the first three clusters, the untreated fruits required approximately the same number of days to reach the 50 to 75 per cent amount of softening and only a slightly longer interval in the fourth. Thus the data indicate that the general difference in reaction between the treated and untreated was due not so much to a retarded rate of softening of the untreated fruits which occurred in the fourth cluster as to the more rapid softening of the treated fruits.

On the surface, the behavior of the pollinated-treated fruits in the first three clusters might tend to indicate a solution to the softening problem. Furthermore, while the data for this observation are not presented in this discussion, it is interesting to note that a relationship, similarly favorable to treatment, was observed even in fruits from emasculated flowers in the first two clusters of the 1947 spring crop. With this evidence in mind it might be assumed that premature softening could be prevented by thorough use of a vibrating device in order to insure pollination prior to treatment, thus achieving conditions and results similar to those obtained with pollinated-treated flowers in these tests.

Before assuming, however, that conditions obtaining in these tests can be duplicated, it is necessary to recall that the spring of 1948 was remarkable for the number of hours and intensity of the sunlight, a condition particularly favorable to natural fruit set. It should also be remembered that, generally speaking, treatment is particularly effective when the days are short and cloudy and the sunlight such as to discourage pollen development and distribution. There is thus no assurance that the pollinated-treated plants in these tests present results which can be unfailingly duplicated under normal greenhouse conditions. Furthermore it should be stated that in 1946, premature softening also occurred in certain commercial houses where cluster vibration was a constant and thorough practise. For these reasons it would be premature to assume that pollination prior to treatment will offset the unfavorable effects here described.

There is at the moment no satisfactory explanation for the marked change in the rate of softening occurring in the pollinated-treated fruits at the beginning of the fourth cluster. The most obvious assumption is that the increased yield of the treated plants induces a depletion of food, as the season advanced and treatments continued, which was not evident in the untreated plants where the yield was unstimulated and average. This explanation seems fallacious, however, in view of the

fact that the effect on the emasculated flowers was immediate and showed no progressive increase in spite of the fact that the yield increased, supposedly inducing a similar food deficiency. Yet it seems logical to suppose that a nutritional factor is responsible, but apparently it is not such as to affect the total yield since the yields in both cases were similar. On the other hand, it may be that total yield is not a satisfactory indication of the depletion of carbohydrates occurring in the treated as opposed to the untreated fruits and that in both cases — emasculated and pollinated — a continuous, excessive withdrawal of carbohydrates is in part responsible for premature softening.

The fruits which in this test softened prematurely showed a considerable amount of green or greenish-tinged gelatinous pulp, but the data appear to indicate an association rather than a causal relationship between the two. This off-color symptom has frequently been found to be associated with poor seed development, and seed development, following treatment with synthetic hormones, is notoriously restricted. This seedlessness may occur even under such conditions as are prevalent in the field in summer when pollen viability and transference seem most assured. To be sure, data obtained over a period of time indicate that indolebutyric acid, or combinations containing this chemical, seem to result in this greenish coloration, but, on the other hand, there is convincing evidence that treated fruits which are wholly red will also soften prematurely. While it is true that both treated lots differed markedly from the untreated in this respect, and while this difference was most apparent in the fourth cluster, yet it is also true that when in the fourth cluster, the two treated groups differed most in respect to coloration, they were, at the same time, most similar in regard to rate of softening. Furthermore, there is little evidence of increased greenness on the side on which softening first begins, a result indicated by a comparison of the data in Table II and apparent in the specimens cut transversely over the last 3 years. Although the above results would indicate that the greenish coloration is not causal in respect to softening, yet further information in regard to this associated characteristic might throw considerable light on the problem.

It is apparent that differences in rate of softening do occur in response to the various chemicals or chemical combinations. For instance, the indolebutyric and beta-naphthoxyacetic acid combination as applied to the emasculated flowers resulted in the most rapid rate of softening. And yet comparison of the fruits resulting from this treatment with those resulting from treatment with orthochlorophenoxypropionic acid as applied to pollinated flowers offers no clue, either to the difference in effect or to the cause of softening. Neither did examination of fruits showing extremes of variation in rate of softening in the fourth cluster show any reason for the condition. Further investigation is highly desirable in the hope that some chemical treatment may be found which will result in firm, high quality fruits and at the same tıme produce the extremely favorable effects already evident, upon total yield and size of fruits.

Considerable data have been taken in regard to the effect of different chemicals and combinations of chemicals upon the seed content and

the pulp development and thickness of the outer wall. These applications have been made in dust, aerosol or liquid forms, at different seasons and on plants both in beds and in pots. These data indicate that a number of these factors influence the thickness of the outer wall, seed coat and pulp development, all of which are associated to some degree with softening and yet not directly the cause. But certainly the outer wall of the fruit frequently is thinner following treatment with the combination of indolebutyric and beta-naphthoxyacetic acids than is the case with certain other chemicals.

As is evident from this discussion, the actual causes of premature softening here described have not been isolated. And yet as the data accumulate it is possible to make certain observations which are at least explanatory. In the first place, the blister-like appearance referred to earlier is merely the visible effect of green or greenish-tinged pulp as it shows through a portion of the outer wall where it is particularly thin (0.2 to 0.3 centimeter). Undoubtedly this variation in wall thickness within a single fruit accounts for some of the criticism which has arisen in regard to treatment. It is also responsible in part for the impression that there is a difference in the rate of softening of the various portions of a single fruit.

In some respects, softening also appears to rest upon what might be termed a purely physical basis. Fruits resulting from treatment tend to show a reduced seed content, with seed coats replacing seeds, and thin vascular strands connecting these seed coats with the placental wall, rather than the thick strands common to well-developed seeds. Obviously, seeds and large vascular strands when immersed in gelatinous pulp contiguous to the outer wall of the fruit will offer more resistance to surface pressure than will the pulp containing seed costs and thin strands common to treated fruits.

It is possible also that the more rapid rate of softening of treated fruits is associated with an increased rate of respiration. Treated fruits, whether developed from pollinated or emasculated flowers, undoubtedly differ in composition from untreated fruits as is indicated by data obtained by Janes (1). Unpublished data obtained by Alban and Ford at Columbus indicated that the respiration rate of emasculated-treated fruits exceeds that of pollinated-treated fruits under certain conditions which may prove to be related to the difference in rate of softening. On the other hand, if treatment does ultimately prove to be associated with increased respiration, such evidence will preclude any hope of an easy solution to the problem of premature softening.

That such a problem exists is due in part, at least, to the demands of commercial distribution. Treatment produces a large, high quality fruit, well-filled with gelatinous pulp, but frequently quite thin as to outer wall. Such a fruit is naturally less capable of withstanding rough handling on the part of packers and shippers as well as prospective customers — especially if the market is slack and sales are slow. The solution may require some degree of compromise between the two objectives.

Three avenues of approach wait further exploration. First, it is important to discover whether or not a high rate of respiration is as-

sociated with treatment; second, it is essential to ascertain the degree to which thinness of outer wall is responsible for premature softening; third, in case respiration is not involved, we shall be encouraged to make further tests of chemicals and combinations of chemicals in the hope that one of these may induce the highly desirable results of treatment, unmodified by its detrimental effects.

## Literature Cited

1. Janes, B. E. Some chemical differences between artificially produced parthenocarpic fruits and normal seeded fruits of the tomato. *Amer. Jour. Bot.* 28: 639–646. 1941.

# Effect of Application of Hormones on Yield of Tomatoes Grown in the Greenhouse[1]

By G. S. RANDHAWA and H. C. THOMPSON,
*Cornell University, Ithaca, N. Y.*

IT is well known that fruit set in tomatoes grown in the greenhouse is rather unsatisfactory during winter days of low light intensity. Gustafson (2) reported that many growth substances caused parthenocarpic development of fruit. Since then several research workers have tried various hormones to increase fruit set of greenhouse tomatoes. Schroeder (7) working with Break O'Day variety of tomatoes tried water sprays of phenylacetic acid, indole propionic acid, indolebutyric acid and indoleacetic acid varying in concentration from 1 to 2500 ppm and lanolin paste of indoleacetic acid 1 to 500 ppm. He reported that when indoleacetic acid in lanolin paste was smeared over the entire ovary, the set of fruit compared favorably with normal. However, the fruits were smaller in size. Howlett (3) made extensive studies and concluded that .3 per cent indolebutyric acid was very effective in obtaining good set and well sized fruits. The chemical was more effective when sprayed as emulsion rather than when applied as paste, except for occasional incidence of blossom end rot. Sometimes the style may enlarge to give pear shaped fruit. Roberts and Struckmyer (6) using Bonny Best, Globe, Marglobe, Michigan State Forcing and Waltham Forcing varieties reported that a single spraying of blossoms with aqueous solutions of β-naphthoxyacetic acid (75 mg per liter) or 2,4–dichlorophenoxypropionic acid (7.5 mg per liter) gave a set of five to seven fruits per cluster. However, they were not effective in checking the nutritional drop of buds. Zimmerman and Hitchcock (9) gave an extensive list of chemicals that could be successfully used for causing parthenocarpic development of tomato fruit. As a result of the studies made by them, they concluded that 2 chlorophenoxypropionic acid, 2,4–dichlorophenoxyacetic acid, 2,5–dichlorobenzoic acid and β-naphthoxyacetic acid were particularly effective. Murneek, Wittwer and Hemphill (5) obtained an increase in yield by spraying flower clusters of tomato plants with β-naphthoxyacetic acid 50 to 100 ppm, and p-chlorophenoxyacetic acid 10 to 20 ppm. Strong (8) obtained an increase in fruit set and fruit size by spraying flower clusters once with 2,4–dichlorophenoxyacetic acid (10 ppm). At the time the experiments reported in this paper were just about completed, Murneek (4) as a result of his studies concluded that β-naphthoxyacetic acid and p-chlorophenoxyacetic acid gave increased yield. However, under cloudy weather conditions puffy fruits were obtained by the use of p-chlorophenoxyacetic acid. He tried some of the newer compounds and indicated that α-o-

[1]Paper No. 311, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

The authors wish to acknowledge the courtesy of Dow Chemical Company, Midland, Michigan, and Dr. P. W. Zimmerman, Boyce Thompson Plant Research Institute for supplying the chemicals used in these studies.

chlorophenoxypropionic acid should be given further trials as it does not cause malformation of leaves.

Studies reported in this paper were undertaken to extend the above-mentioned research. It seemed that some of the newer and more promising hormones needed further testing and that more should be known regarding the concentration and the most efficient and effective methods of application of these materials.

## Materials and Methods

The Valiant variety of tomatoes was grown in the greenhouse during three seasons, spring 1947, fall 1947 and spring 1948. This variety was selected to study its response to the application of different hormones under wide range of environmental conditions, though in this paper results of only spring and fall greenhouse experiments are reported. The plants were spaced in the groundbed of the greenhouse 1½ feet apart, while the distance between rows was 2½ feet. Hormone solutions were prepared by dissolving the chemical first in a small quantity of ethyl alcohol (10 cc) and later diluting with water to the desired concentration. Temperature of the greenhouse was 65 degrees F (night) to 75 degrees F (day), except after the middle of April when it rose above 75 degrees F. Fertilizer (5-10-5) was added to the soil at the rate of 5 pounds per 100 square feet. Further applications of fertilizer were made at different times to maintain a high level of fertility. Plants were shaken every alternate day to ensure pollination.

Fruits from the first three replications of the fall crop of 1947 were used for ascorbic acid and total soluble solids determinations. A Zeiss hand refractometer was used to determine the soluble solids from the juice of the first three fruits maturing on the first cluster. Soluble solids are expressed as percentages of sucrose. The hand refractometers are calibrated to read in terms of percentage of sucrose, although other soluble solids affect the reading. The figures given in column 4 of Table I represent means of nine fruits from each treatment, with a few exceptions, where the number of fruits was smaller.

Ascorbic acid determinations were made, from the same fruits that were used for soluble solid analysis. The method suggested by "The Association of Vitamin Chemists, Inc." (1) with certain modifications in the preparation of sample, was followed.

## Experimental Results

Results obtained from various experiments are presented separately, as the experiments were conducted during various portions of the year and involved different treatments.

*The 1947 Spring Experiments:*—These experiments were more or less preliminary, designed to eliminate the less desirable materials. Tomato seed was sown on January 6, 1947; the seedlings were transplanted in greenhouse bed on February 21. The first cluster of every

plant was sprayed three times with one of the following materials at each of the indicated concentrations:

(a) $\beta$-naphthoxyacetic acid at 50, 75, and 100 ppm.
(b) p-chlorophenoxyacetic acid at 10, 20, 30, 50, 75, and 100 ppm.
(c) $\alpha$-2,4–dichlorophenoxypropionic acid at 5, 7.5 and 10 ppm.
(d) $\alpha$-ortho-chlorophenoxypropionic acid at 25, 50, and 75 ppm.
(e) 2,5–dichlorobenzoic acid at 100, 200 and 300 ppm.
(f) "Seedless-set" (as directed by manufacturers - Plant Products Corporation, Blue Point, N. Y.)

The yield data for the first cluster showed that only six treatments gave an increased yield over the check plants. Treatment with "Seedless-Set" yielded fruit weighing 1067 grams; treatment with 2,5–dichlorobenzoic acid (100 ppm) 918 grams; with p-chlorophenoxyacetic acid (75 ppm) 897 grams; with $\beta$-naphthoxyacetic acid (50 ppm) 824 grams; with $\alpha$-o-chlorophenoxypropionic acid (50 ppm) 796 grams; and with p-chlorophenoxyacetic acid (20 ppm) 793 grams. Average weight of fruit for the comparable check was 744 grams. However, most of the fruits from plants treated with p-chlorophenoxyacetic acid (75 ppm) had unfilled locules.

The second and third clusters were sprayed at three different times with the hormone solutions listed above. In block 1, the clusters were sprayed when one-third of the flowers were open; in the second block when two-thirds of the flowers were open and in the third, when all the flowers were open. It was noticed that yield was low when a cluster with only one-third flowers open was treated. Differences in yield were outstanding, particularly wherever high concentrations of hormones were used. Small buds present on the clusters at the time of spraying first became pale, then degenerated and dropped.

*The 1947 Fall Experiment:*—Seed was sown for this crop on August 21; the seedlings were transferred to the flats and finally transplanted in the groundbed in the first week of October. The five hormones used in this experiment were applied at three different times to the first three clusters of each plant.

(a) When one-half of the flowers in a cluster were open.
(b) When all the flowers in a cluster were open and,
(c) At both the above stages (two sprayings).

Individual plants were used as plots. Treatments given in Table I were replicated six times. The total weight of fruit and average number of fruits per plant for the three treated clusters along with other data obtained from this experiment are presented in Table I.

It is clear from Table I that most of the hormone treatments gave significantly higher yields than the check. However, factorial analysis of the data showed that there was no significant difference between the various hormones or the timing of their application. Increase in number of fruits set was significant only at a 19:1 level for certain hormone treatments. Factorial analysis also revealed that

TABLE I—EFFECT OF DIFFERENT TREATMENTS ON YIELD, NUMBER OF FRUITS, AVERAGE WEIGHT PER FRUIT, SOLUBLE SOLIDS AND VITAMIN C CONTENT OF TOMATOES (FALL 1947)

| Treatments | Fruit Weight Per Plant (Gms) | Number of Fruits | Average Weight Per Fruit (Gms) | Soluble Solids (Per Cent) | Ascorbic Acid Mg Per 100 Gm |
|---|---|---|---|---|---|
| 1. β-naphthoxyacetic acid (50 ppm), one half flowers open | 962** | 10.0* | 91 | 4.8 | 24.6 |
| 2. β-naphthoxyacetic acid (50 ppm), all flowers open | 898** | 10.3* | 87 | 5.3 | 28.4 |
| 3. β-naphthoxyacetic acid (50 ppm), (1) + (2) stages | 1121** | 12.8* | 87 | 5 3 | 26 3 |
| 4. Seedless, one half flowers open | 832* | 8.5 | 87 | 4.7 | 23.5 |
| 5. Seedless, all flowers open | 772 | 8.8 | 92 | 5.1 | 26.4 |
| 6. Seedless, (1) + (2) stages | 995** | 10.8* | 92 | 5.2 | 30 2 |
| 7. p-chlorophenoxyacetic acid (25 ppm), one half flowers open | 1003** | 9.3 | 87 | 5.5 | 29.3 |
| 8. p-chlorophenoxyacetic acid (25 ppm), all flowers open | 962** | 10 2* | 94 | 5.2 | 28.0 |
| 9. p-chlorophenoxyacetic acid (25 ppm), (1) + (2) stages | 905** | 9.7 | 98 | 5.9 | 29.8 |
| 10. α-o-chlorophenoxypropionic acid (50 ppm), one half flowers open | 891* | 9.3 | 95 | 5.1 | 29.5 |
| 11. α-o-chlorophenoxypropionic acid (50 ppm), all flowers open | 839* | 9.5 | 88 | 5.3 | 25.5 |
| 12. α-o-chlorophenoxypropionic acid (50 ppm) (1) + (2) stages | 973** | 11.2* | 108 | 5.3 | 28.3 |
| 13. 2, 5-dichlorobenzoic acid (100 ppm), one half flowers open | 794 | 8.8 | 90 | 6.1 | 27.2 |
| 14. 2, 5-dichlorobenzoic acid (100 ppm), all flowers open | 962** | 10.3* | 93 | 5.2 | 29.6 |
| 15. 2, 5-dichlorobenzoic acid (100 ppm), (1) + (2) stages | 1022** | 11.3* | 90 | 5.3 | 26.8 |
| 16. Check | 604 | 7.4 | 85 | 5.1 | 26.7 |
| L.S.D. (.05) | 218 | 2.4 | | N.S. | N.S. |
| (.01) | 289 | — | | | |

two applications as compared to one increased the number of fruits set. It seems that both increase in number of fruits and average weight per fruit were responsible for the great increase in yield. There seems to be a tendency for increase in soluble solids resulting from the application of hormones. However, there was great variation from plant to plant and even in the fruits on the same cluster.

Ascorbic acid determinations made from the treated and untreated fruits did not show any appreciable difference.

Fruits from treated plants were deep red in color and larger in size than the untreated ones. Nine fruits from each treatment were cut and examined. Most of the treated fruits were seedless, more meaty and sweeter than check. Occasionally a pear shaped fruit or one with small hollow cavities or greenish jelly in the locules was obtained, but the number of such fruits was very low and they could be found in almost all treatments including the check.

Though a highly significant increase in yield was obtained by the use of hormone sprays, the superiority of any one of the hormones over others was not clearly established from the results of this experiment. Another experiment was started in spring of 1948.

*The 1948 Spring Experiment No. 1:*—Seed was sown for the spring crop on January 16. Later on 81 uniform, vigorous growing plants were transplanted in the groundbed of greenhouse on March 29, 1948. There were guard plants all around to eliminate border

effect. A Latin square design with nine treatments was set up. Spraying was started when three to four flowers on most of the plants had opened. Each cluster was sprayed twice at weekly intervals and only three clusters on each plant were sprayed. Total yield of fruit from the three treated clusters is presented in Table II. The fruit harvested in the first 2 weeks, referred to as early yield, is presented separately in the first column of the table, to show the effect of different hormones on maturity of the fruit.

Data showing the characteristics of fruits under study are presented in Tables II and III.

TABLE II—EFFECT OF DIFFERENT HORMONE TREATMENTS ON EARLY YIELD, TOTAL YIELDS, NUMBER OF FRUITS AND INCIDENCE OF BLOSSOM END ROT IN TOMATOES IN 1948 SPRING (MEAN PER PLANT)

| Treatments | Weight of Early Fruit | Total Weight of Fruits | Number of Fruits | Average Weight Per Fruit | Per Cent Blossom End Rot |
|---|---|---|---|---|---|
| 1. β-naphthoxyacetic acid (50 ppm) | 521** | 1419* | 13.7 | 104 | 17.8 |
| 2. o-chlorophenoxyacetic acid (50 ppm) | 201 | 1128 | 13.3 | 85 | 8.3 |
| 3. α-o-chlorophenoxypropionic acid (50 ppm) | 442* | 1413* | 13.7 | 103 | 17.1 |
| 4. p-chlorophenoxyacetic acid (25 ppm) | 405* | 1357* | 13.6 | 100 | 31.1 |
| 5. 2,4,5-trichlorophenoxyacetic acid (10 ppm) | 428* | 1165* | 13.8 | 85 | 18.5 |
| 6. 2,5-dichlorobenzoic acid (100 ppm) | 230 | 1453* | 17.1* | 85 | 7.8 |
| 7. BNA (25 ppm) +p-ClPA (40 ppm) | 324 | 1190* | 14.1* | 84 | 33.8 |
| 8. "Seedless-set"* | 267 | 966 | 12.3 | 78 | 27.9 |
| 9. Check | 213 | 720 | 10.8 | 67 | 13.4 |
| L.S.D. (.05) | 180 | 442 | 3.2 | | |
| (.01) | 241 | | | | |

*Application of "Seedless-set" resulted in increased yield in first two experiments. Lack of response in this case suggests that it might have deteriorated during storage for 1 year.

TABLE III—EFFECT OF DIFFERENT TREATMENTS ON THE COLOR OF PULP, DEVELOPMENT OF SEEDS AND CAVITIES IN THE LOCULES

| Treatment No. | Number of Fruits | Per Cent of Fruit Falling in the Various Categories | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Color of the Pulp | | | Condition of Locules | | Presence of Seeds | |
| | | Red | Pale Red | Greenish | Well Filled | Partially Filled | Present | Absent |
| 1 | 62 | 72.6 | 24.2 | 3.2 | 100.0 | 0.0 | 38.7 | 61.3 |
| 2 | 55 | 61.8 | 38.2 | 0.0 | 98.2 | 1.8 | 69.1 | 30.9 |
| 3 | 45 | 77.8 | 17.8 | 4.4 | 93.3 | 6.7 | 61.9 | 38.1 |
| 4 | 31 | 77.4 | 22.6 | 0.0 | 100.0 | 0.0 | 51.6 | 48.4 |
| 5 | 52 | 69.2 | 21.2 | 9.6 | 94.2 | 5.8 | 63.5 | 36.5 |
| 6 | 66 | 77.3 | 22.7 | 0 0 | 100.0 | 0.0 | 54.5 | 45.5 |
| 7 | 49 | 77.6 | 10.2 | 12.2 | 89.8 | 10.2 | 42.9 | 57.1 |
| 8 | 53 | 83.0 | 13.2 | 3.8 | 100.0 | 0.0 | 75.5 | 24.2 |
| 9 | 24 | 75.0 | 25.0 | 0.0 | 100.0 | 0.0 | 91.6 | 8.4 |

It is evident from Table II that total yield was increased by most of the treatments. However, early yield was increased only in case of treatments Nos. 1, 3, 4 and 5. Number of total fruits produced tended to be increased by the application of hormones, although a significant difference for the check was obtained in only two cases. Here again, it seems that greater total yield resulted from increase in both number and weight of fruit. Incidence of blossom end rot averaged

highest with treatments involving the use of p-chlorophenoxyacetic acid.

Shape of the fruit was not affected by various treatments, except that a few pear shaped fruits were noticed on plants treated with 2, 4,5-trichlorophenoxyacetic acid (10 ppm).

Results presented in Table III show that application of β-naphthoxyacetic acid + p-chlorophenoxyacetic acid produced more fruits with greenish jelly and partially filled locules than other treatments. The same effects were exhibited, though to a lesser degree, in case of treatments No. 3 and 5. Application of hormones in all cases depressed seed formation. On the whole, treated fruits were adjudged as more meaty and sweet as compared to check.

*1948 Spring Experiment No. 2:*—Another experiment was set up in the spring of 1948, to study the effect of application of different hormones to the soil on the growth and fruiting of the tomato plant. Uniform, vigorously growing plants were transferred to 12-inch pots on March 29, 1948. They were divided into four groups on April 16, when two to three flowers on the first cluster of most of the plants had opened. Aqueous solutions of hormones were applied to the soil as follows:

Treatment No. 1 50 ppm o-chlorophenoxyacetic acid, 100 cc thrice, at weekly intervals.
Treatment No. 2 50 ppm α-o-chlorophenoxypropionic acid, 100 cc thrice, at weekly intervals.
Treatment No. 3 100 ppm 2,5-dichlorobenzoic acid, 100 cc twice, at weekly intervals.
Treatment No. 4 check.

The general appearance of the treated plants was not much affected, except those treated with o-chlorophenoxyacetic acid. These were yellowish green and comparatively weak, resembling plants infected with virus mosaic. Their top growth was significantly poorer than those treated with α-o-chlorophenoxypropionic acid and 2,5-dichlorobenzoic acid (Table IV).

Although there was no statistically significant difference between root weight of different groups of plants, the data tend to indicate that there was some stimulation of growth in case of plants treated with α-o-chlorophenoxypropionic acid.

The average weight per fruit before July 1, for all hormone treatments taken together was 166 grams as compared with 93 for the check. This difference is statistically significant. However, when

TABLE IV—MEAN YIELD PER PLANT, AVERAGE FRUIT WEIGHT, TOP AND ROOT GROWTH PER PLANT UNDER DIFFERENT TREATMENTS

| Treatment No. | Yield of Fruit (Gm) | Fruit Size Before July 1 (Gm) | Fruit Size After July 1 (Gm) | Tops (Fresh Weight) (Oz) | Roots (Dry Weight) (Gm) |
|---|---|---|---|---|---|
| 1 | 1489 | 147 | 157 | 19.5 | 11.1 |
| 2 | 1592 | 154 | 104 | 30.25 | 15.7 |
| 3 | 1669 | 196 | 133 | 28.0 | 10.5 |
| 4 (check) | 1549 | 93 | 101 | 25.5 | 10.3 |

different hormone treatments are considered separately, it was found that only treatment No. 3 had significantly larger fruit size than the check. The average weight per fruit was decreased in case of plants treated with α-o-chlorophenoxypropionic acid and 2,5 dichlorobenzoic acid after the first of July. The presence of seeds observed on July 5 shows that the hormones lost their effect within 7 to 8 weeks. It is possible that they were leached out of the soil, absorbed and fixed by soil colloids or decomposed and thus rendered ineffective.

The total yield of the plant does not seem to have been influenced under these conditions to any appreciable degree.

The fruits harvested from different treatments were cut and tasted. The fruits treated with α-o-chlorophenoxypropionic acid and 2,5–dichlorobenzoic acid were rich red and more meaty as compared to untreated ones. They were adjudged as sweeter and richer in flavor than the ones treated with o-chlorophenoxyacetic acid and check. However, there appeared in all the treated groups some fruits with greenish jelly which was not considered very desirable from the appearance point of view. There were no misshapened fruits or fruits with hollow locules on treated plants such as are sometimes obtained when tomato blossoms are sprayed with hormones.

## Summary

Several hormones were applied as sprays in different concentrations to overcome poor set and small size of fruit in tomatoes obtained during winter under conditions of low light intensity.

Total yield was increased by spraying the flower clusters with β-naphthoxyacetic acid (50 ppm); α-o-chlorophenoxypropionic acid (50 ppm); p-chlorophenoxyacetic acid (25 ppm); 2,4,5-trichlorophenoxyacetic acid (10 ppm) and 2,5–dichlorobenzoic acid (100 ppm). Increase in both early and total yield was obtained by the use of first four hormones.

Spraying a flower cluster twice, once when half the flowers were open and second when all the flowers had opened resulted in greater set of fruits than was obtained from the untreated plants.

Spraying the flower clusters with hormones did not make any appreciable difference in the soluble solids and ascorbic acid content of the fruits.

Tomatoes from treated plants were uniform, rich red in color and larger in size than the check, except for an occasional misshapen fruit, one with unfilled locules, or greenish jelly.

Application of 2,5–dichlorobenzoic acid to the soil increased size of tomato fruits.

## Literature Cited

1. Association of Vitamin Chemists, Inc. Methods of Vitamin Assay. 143–153. 1947.
2. Gustafson, F. G. Inducement of fruit development by growth-promoting chemicals. *Proc. Nat. Acad. Sci.* 22: 628–636. 1936.
3. Howlett, F. S. Effect of indolebutyric acid upon tomato fruit set and development. *Proc. Amer. Soc. Hort. Sci.* 39: 217–227. 1941.
4. Murneek, A. E. Results of further investigations on the use of hormone sprays in tomato culture. *Proc. Amer. Soc. Hort. Sci.* 50: 254–262. 1947.

5. ———— WITTWER, S. H., and HEMPHILL, D. D. Supplementary hormone sprays for greenhouse grown tomatoes. *Proc. Amer. Soc. Hort. Sci.* 45: 371–381. 1944.
6. ROBERTS, R. H., and STRUCKMEYER, B. E. The use of sprays to set greenhouse tomatoes. *Proc. Amer. Soc. Hort. Sci.* 44: 417–427. 1944.
7. SCHROEDER, R. A. Application of plant hormones to tomato ovaries. *Proc. Amer. Soc. Hort. Sci.* 35: 537–538. 1937.
8. STRONG, M. C. Use of 2,4-D for the improvement of greenhouse tomato production. *Mich. Agr. Exp. Sta. Quart. Bul.* 28(3): 216–225. 1946.
9. ZIMMERMAN, P. W., and HITCHCOCK, A. E. Substances effective for increasing fruit set and inducing seedless tomatoes. *Proc. Amer. Soc. Hort. Sci.* 45: 353–361. 1944.

# The Effect of Maturity and Storage on Germination of Butternut Squash Seed[1]

By Robert E. Young, *Massachusetts Agricultural Experiment Station, Waltham, Mass.*

Ever since Butternut squash became popular, growers have had trouble obtaining seed that would germinate satisfactorily. Most of them felt it was necessary to store the squash for 2 or 3 months in order to obtain good seed, and this practice is now followed by those who save their own seed.

When seedsmen started to produce this seed on a large scale, they also had trouble in obtaining high germinating seed year after year.

In a preliminary experiment to determine the nature of the problem of producing high germinating seed, a large number of mature squash were selected at harvest and placed in storage. To determine the effect of maturity, another lot of squash was selected which was sufficiently mature for market but not as much so as the first lot. These two lots were distinguished by a very slight difference in color.

Starting after harvest, 25 squash of each lot were removed from storage every 2 weeks and the seeds removed and dried. The last lot was removed December 19th, after approximately 2½ months in storage. The seeds were counted and weighed, and it was found that the mature squash produced 24.6 grams of seed per squash, while the immature fruits contained only 18.1 grams. Storage did not change these figures appreciably.

Replicated lots of 100 seeds were weighed and it was found that the mature squash produced seed that weighed 7.78 grams per 100 at the start but with storage the weight increased to 8.12 grams. The immature squash produced seed that was much lighter, weighing only 5.32 grams per 100 seed at the start of storage, but the weight increased steadily to 6.23 grams. Although the seeds from immature squash increased in weight, they never approached the weight of those from mature fruits.

After all the seeds were removed from the squash, germination studies were started by placing squash seeds on blotting paper in a germinator. The seed removed from mature squash at the start of the storage had an average germination of 90.8 per cent, and the germination increased to 96.2 per cent with 2 weeks' storage. It changed very little with each storage period, but the seed from squash stored to December 19th germinated 98.4 per cent.

Only 19 per cent of the seed from immature squash at the start of the storage period germinated, and only 7 squash of the 25 produced any viable seed. It was obvious that several squash had been placed in the wrong group.

The germination of seed of the immature squash increased with each storage period, with a maximum of 67.2 per cent. In the last group all of the squash had some viable seed. Some squash in the

[1]Contribution No. 685 of the Massachusetts Agricultural Experiment Station.

immature group produced large seeds which could not be removed by cleaning mills and that would not germinate.

The squash seed germinated in soil showed more variation than that germinated in the laboratory.

To obtain good germination, it is necessary to pick only very mature Butternut squash for seed. While storage will improve the size and germination of the seed, it will not make good seed from green squash. The farmer, however, need not store the squash which he plans to save for seed.

Butternut squash continues to set fruit up to frost. Since the mature squash differs so little from the immature in appearance, seedsmen may find that their workers need some special training to enable them to recognize the slightly darker buff color of the fully mature squash.

# Pre-Emergence Weed Control for Tomato Plants in Cold Frames

By P. P. Nixon and G. E. Smith, *Campbell Soup Company, Camden, N. J.*

Hand weeding of tomato seedlings grown in cold frames is usually necessary to produce early plants of good quality. This operation not only requires a large amount of labor, accounts for some glass breakage, but may raise the final cost of the seedling above that of field grown southern plants. Since it is essential to plant early in the spring, little can be done to kill weeds before seedings are made.

Various petroleum oils have been successfully used as selective herbicides for controlling weeds in carrots and parsley. Tomato seedlings are killed by these oils, but frequently weed seedlings are numerous in cold frames or hot beds before the tomato seedlings emerge. Preliminary work in 1947 indicated that tomato plants were of better quality when the soil was given a pre-emergence application of oil. The study reported here was conducted in 1948 to determine if application of Stoddard's Solvent, applied when a large number of weed seed had germinated and before the tomato plants emerged, would kill weeds without injuring the tomatoes and reduce the hand labor required in producing tomato plants.

## Methods

Sassafras sandy loam soil in permanent cold frames using 3½ by 7-foot sash in 60 sash units was plowed 4 days previous to planting. Three days before planting the soil was disced and 500 pounds of 3–8–8 fertilizer applied with a grain drill. On March 26, 1948 the soil was disced and meeker harrowed, raked lightly, marked off in 8 inch rows ½ to ¾ inches deep and Garden State tomato seed sown at the rate of 1½ pounds per 60 sash. The rows were filled in level with a hand drag, rolled with a light roller, and the sash put in place.

The soil was at optimum moisture content at time of planting and no supplementary watering was done until plants had been treated (with oil spray) and grown to a 1-inch height.

On April 3, *Polygonum sp.* (smart weed), *Chenopodium album* (lambs quarter), *Stellaria* (chick weed), *Amaranthus* (red root) and *Galensogo* were present, tomato seed had sprouted but did not appear above the soil surface at this date.

Oil was applied on April 3, using an engine powered wheel barrow type sprayer. The boom was 3 feet in width carrying four fan-type nozzles attached to a handle which also served as portion of the feed line. The sash were removed and boom pushed and pulled across the bed. Oil was not measured for each individual bed but the amount used averaged 5 gallons per 60 sash. Twelve, 60-sash frames were completely sprayed, one frame which supplied the data in Table I was sprayed in 6-sash plots with a 6-sash check plot between each sprayed section. There were five replications of sprayed and check plots.

## Results

The application of the solvent resulted in rapid wilting and killing of the weeds. No toxic effect was noted on the tomatoes that emerged 1 to 2 days following the application of the solvent.

On May 19 one row of plants was pulled from each replication and counts were made of the number of usable plants and the fresh weight of weeds recorded.

TABLE I—Effect of Stoddard's Solvent on Weed Control and Yield of Tomato Plants (Weight and Yield Per 7 Feet of Row)

| Treated With Solvent | | | | Not Treated | | | |
|---|---|---|---|---|---|---|---|
| | Weight (Grams) | | | | Weight (Grams) | | |
| Plot | Weeds | Tomato Plants | Number Plants | Plot | Weeds | Tomato Plants | Number Plants |
| 1 | 69.1 | 190.0 | 35.0 | 2 | 575.2 | 93.9 | 20.0 |
| 3 | 111.0 | 180.0 | 32 0 | 4 | 279.1 | 47.0 | 10.0 |
| 5 | 28.6 | 317.0 | 42.0 | 6 | 112.1 | 55.1 | 12.0 |
| 7 | 8.2 | 154.6 | 28.0 | 8 | 119.5 | 24.0 | 7.0 |
| 9 | 29.0 | 144.0 | 25.0 | 10 | 174.8 | 115.6 | 23.0 |
| Average | 49.2 | 198.7 | 32.4 | Average | 252.1 | 67.1 | 14.4 |

The data given in Table I show that the application of Stoddard's Solvent greatly reduced the weed growth and increased the number and size of plants that were pulled. Although some of the replications were located in sections of the bed having a greater weed population than others, all of the treated replications produced more and larger tomato plants than where the weeds competed for nutrients and moisture. The application of the solvent reduced the fresh weight of weeds from 252.1 to 49.2 grams per row and increased the number of plants pulled from 14.4 to 32.4 per row, or an increase of 225 per cent in number of plants. Not only were the tomato plants from the area treated with solvent larger and more stocky than where there was competition from weeds, but the yield of plants was greater, and root system superior to those from other frames which were hand weeded during the growing period. Although some weed seed germinated later, the growth of tomato seedlings was sufficiently advanced that these weeds made slow growth. Observation of the beds indicated that the best weed control was secured when the tomato seed were deeply covered.

A crew of eight men were able to remove sash, apply oil and replace the sash on a 60-sash frame in 15 to 20 minutes. At a later date adjacent frames were weeded by hand. Ten workers were able to weed only four, 60-sash frames in 10 hours.

## Discussion

Applications of Stoddard's Solvent to tomato plant beds when weeds were small and before tomato seedlings emerged gave satisfactory control without injury to tomato plants. Frequent examination of the rate of germination of the tomato seed were made. Weed control was satisfactory when the oil was applied 20 to 24 hours prior to the emergence of the tomatoes. Best results were obtained when the tomato seed were planted deep so that a maximum number of weed seed germinated before the tomato seedlings emerged.

# Effect of Fruit Setting Treatment, Variety and Solar Radiation on Yield and Fruit Size of Greenhouse Tomatoes[1]

By S. H. WITTWER, *Michigan State College, East Lansing, Mich.*

THAT the so-called "hormone" sprays can increase yield and fruit size in greenhouse-grown tomatoes is well established. They are especially effective during seasons and in region having short photoperiods or prevailingly low light intensities. The magnitudes of yield and size increases reported in several producing areas have, however, been quite variable (3, 4, 5, 7, 8). A possible factor involved in the different responses to hormone sprays is perhaps that of variety. Herein reported are the effects of commercial vibration practices, used alone and in combination with hormone sprays as aids for improving fruit set and size on several of the leading greenhouse tomato varieties, grown both as spring and fall crops during the 1947 season at East Lansing, Michigan.

## METHODS

The tomato plants were grown in the vegetable crops greenhouse at Michigan State College. Culture was similar to commercial production. For the seven varieties in the spring crop, seed were sown and the plants set into ground beds January 3 and March 10, respectively, while planting the seed and setting the plants occurred July 8 and August 25, respectively, for the nine varieties included in the fall crop. The plants were set in 3-foot rows with a spacing of 18 inches between plants in the row, and trained to a single stem. For both spring and fall crops, three plants of each variety were randomized in each of eight blocks. A split-plot design was used in which one of the three plants of each variety in each block was left as a control without treatment. The flower clusters of the second were vibrated on alternate days by means of the doorbell type commercial vibrator, the third plant received the vibration treatment of the second, and, in addition, a weekly spray of hormone solution containing 40 parts per million of B-naphthoxyacetic acid and 10 parts per million of p-chlorophenoxyacetic acid.[2] The hormone spray was applied to the inflorescences, having open flowers, by means of the quart size "shur-shot" sprayer[3] operated at approximately 50 pounds pressure. Each treatment was repeated eight times on single plants of a given variety (single plants served as replicates). Fruit were harvested twice weekly, the harvest period for the spring crop extending from May 19 to August 9, and from November

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The author wishes to express his appreciation to Mr. G. A. Crabb, Jr., supervisor of the hydrologic research project, U. S. D. A. Soil Conservation Service, East Lansing, Michigan, for the data on solar radiation, and to Mr. W. H. F. Saia for his assistance in graphically presenting the data.

[2]Grateful acknowledgment is extended to Lawrence Southwick of the Dow Chemical Company for supplying liberal quantities of these chemicals.

[3]Manufactured by the Milwaukee Sprayer Manufacturing Company, Inc.,

18 to January 15 for the fall crop. Fruit of all sizes, if free from serious defects, were considered in the yield and fruit size records. Data were analyzed and significant differences determined by the usual procedures and methods employed in the analysis of variance.

## Results

Table I and Fig. 1 present the yield data for the seven spring- and nine fall-crop varieties, along with the three fruit-setting treatments. With both crops there were not only marked differences in the averages (Table I) for variety yield response but in fruit setting treat-

TABLE I—Effect of Variety and Fruit Setting Treatment on Yield of Greenhouse Tomatoes

| Variety | Pounds of Marketable Fruit Harvested Per Plant | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Controls No Treatment | | Vibrated | | Vibrated Plus Hormone | | Averages | |
| | Spring Crop | Fall Crop | Spring Crop | Fall Crop | Spring Crop | Fall Crop | Spring Crop | Fall Crop |
| Spartan Hybrid | 9.5 | 2.3 | 12.0 | 3.7 | 14.0 | 5.2 | 11.8 | 3.7 |
| Michigan State Forcing | 8.1 | 2.5 | 9.8 | 4.5 | 13.3 | 5.3 | 10.4 | 4.1 |
| Stokesdale × Cooper's Special | 9.8 | 2.3 | 9.2 | 3.5 | 12.2 | 4.0 | 10.4 | 3.3 |
| Globe A | 6.3 | 1.0 | 8.2 | 3.2 | 11.2 | 4.4 | 8.6 | 2.9 |
| Northern Hybrid | 11.5 | 3.3 | 10.7 | 4.6 | 12.3 | 5.1 | 11.5 | 4.3 |
| Improved Bay State | 11 6 | 2.7 | 12.2 | 4.3 | 11.5 | 4.9 | 11.8 | 4.0 |
| Washington State Forcing | 8.3 | 1.6 | 9.4 | 3.1 | 9.1 | 3.0 | 8.9 | 2.6 |
| Potentate | — | 2.5 | — | 2.7 | — | 3.4 | — | 2.9 |
| Long Calyx Forcing | — | 1.5 | — | 2.3 | — | 4.1 | — | 2.6 |
| Averages | 9.3 | 2.2 | 10.2 | 3.5 | 11.9 | 4.4 | 10.5 | 3.4 |

| | *Spring Crop* | | *Fall Crop* | |
|---|---|---|---|---|
| Least Significant Differences | *.05* | *.01* | *.05* | *.01* |
| Variety | 1.23 | 1.65 | 0.69 | 1.01 |
| Treatment | 0.83 | 1.06 | 0.61 | 1.02 |
| Variety × Treatment | 2.26 | 3.01 | | |

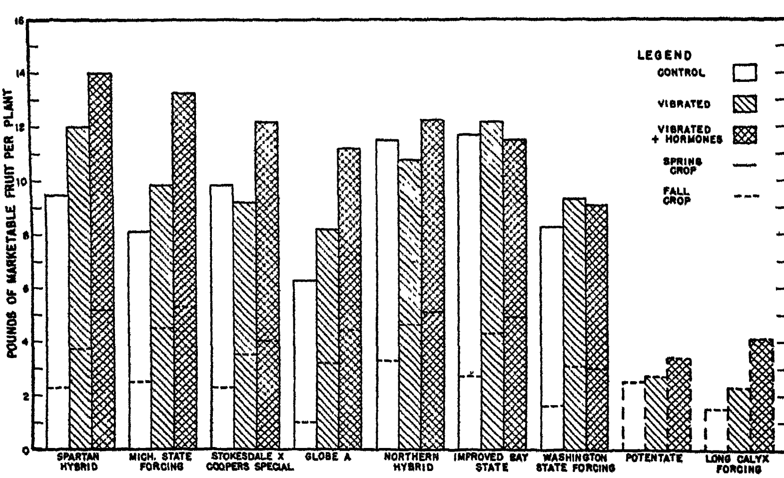


Fig. 1. Effect of fruit setting treatment and variety on yield of greenhouse tomatoes.

ments as well. In the spring crop, Spartan Hybrid, Michigan State Forcing and Globe A gave a remarkable increase in yield when the vibration-hormone combination was used. This was in sharp contrast to Northern Hybrid, Improved Bay State, and Washington State Forcing, all of which gave no significant yield difference when supplementary fruit setting treatments were used. Such varietal differences to treatment provided a statistically significant interaction with yield (Table I). In the fall crop, all nine varieties gave a highly significant yield increase, compared with controls, when the flower clusters received the vibration-hormone combination. Even with vibration alone, yield increases above the controls were significant with all except the Danish forcing variety, Potentate. Variety interactions with treatment were not evident since in the fall all responded favorably. The graphical presentation of the data in Fig. 1 illustrates the marked contrast in total yields of the two crops, as well as interesting variety-treatment interactions.

With respect to fruit size, as recorded in Table II and Fig. 2, strik-

TABLE II—EFFECT OF VARIETY AND FRUIT SETTING TREATMENT ON FRUIT SIZE OF GREENHOUSE TOMATOES

| Vareity | Fruit Size Expressed as Ounces Per Fruit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Controls No Treatment | | Vibrated | | Vibrated Plus Hormone | | Averages | |
| | Spring Crop | Fall Crop | Spring Crop | Fall Crop | Spring Crop | Fall Crop | Spring Crop | Fall Crop |
| Spartan Hybrid | 3.47 | 4.28 | 4.69 | 4.43 | 4.84 | 4.28 | 4.33 | 4.33 |
| Michigan State Forcing | 2.89 | 4.25 | 3.85 | 5.25 | 5.01 | 4.77 | 3.92 | 4.76 |
| Stokesdale × Cooper's Special | 4.26 | 4.08 | 4.36 | 3.79 | 4.64 | 3.84 | 4.42 | 3.90 |
| Globe A | 4.04 | 4.64 | 4.13 | 4.80 | 6.04 | 4.56 | 4.74 | 4.67 |
| Northern Hybrid | 3.44 | 3.90 | 3.69 | 4.13 | 4.38 | 3.55 | 3.84 | 3.86 |
| Improved Bay State | 2.39 | 3.20 | 2.99 | 2.94 | 3.21 | 2.83 | 2.86 | 2.99 |
| Washington State Forcing | 3.07 | 3.46 | 3.41 | 3.66 | 3.73 | 3.11 | 3.40 | 3.41 |
| Potentate | — | 2.91 | — | 2.44 | — | 2.90 | — | 2.75 |
| Long Calyx Forcing | — | 3.38 | — | 3.61 | — | 3.89 | — | 3.63 |
| Averages | 3.37 | 3.79 | .873 | 3.89 | 4.55 | 3.75 | 3.93 | 3.81 |

| | Spring Crop .05 | Spring Crop .01 | Fall Crop .05 | Fall Crop .01 |
|---|---|---|---|---|
| Least Significant Differences | | | | |
| Variety | 0.45 | 0.59 | 0.40 | 0.58 |
| Treatment | 0.28 | 0.37 | 0.36 | 0.59 |
| Variety × Treatment | 0.80 | 1.06 | | |

ing differences in varieties were noted, but in contrast to yields of the same crop, a significant increase in fruit size was evident with all varieties in the spring, especially from the vibration-hormone treatment. With Spartan Hybrid, Michigan State Forcing, and Improved Bay State vibration alone was sufficient to produce a significant difference. Alterations in fruit size arising from supplementary fruit setting treatments in the fall crop did not follow the regular pattern of increases evident from vibration alone and the vibration-hormone combination in the spring. In a comparison of fruit sizes in the spring and fall crops (Fig. 2), there were, in general, larger fruit harvested from the controls in the fall, while on the vibration-hormone treated plants, larger fruit were produced in the spring. Averages of fruit sizes for all varieties and treatments in the two crops (Table II) showed no significant differences.

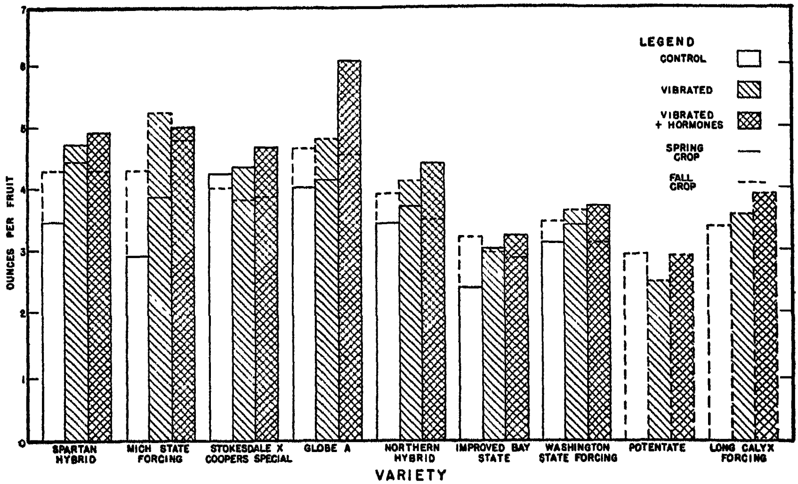


FIG. 2. Effect of fruit setting treatment and variety on fruit size of greenhouse tomatoes.

## DISCUSSION

Varietal differences in yield response of the spring crop of greenhouse tomatoes to fruit setting treatments are well illustrated in Fig. 1. Spartan Hybrid, Michigan State Forcing, Stokesdale x Cooper's Special, and Globe A are large-fruited and their dominant parentage is that of the American globe type of tomato. Such varieties tend to lack in fruitfulness when grown during short photoperiods or in seasons or areas having low light intensities — conditions analagous to those prevailing in many northern states in winter. Within the floral parts, the pistils tend to elongate and extend beyond the stamen cone (1, 2). Schneck (6) pointed out that English forcing types, or those with dominant English forcing parentage, develop much shorter pistils favoring self-pollination even in adverse climates. It was also emphasized (6) that more viable pollen is consistently produced by the English types and less is required, since fewer seeds are present, than for the American globe type of forcing tomato. Northern Hybrid, Improved Bay State, and Washington State Forcing have fruit setting abilities characteristic of English forcing types and because of this, gave little or no response to either vibration alone or vibration combined with hormone sprays in the spring crop.

That fruit size can be increased significantly by fruit setting aids in the spring crop (Fig. 2), independent of yield in the English forcing types, is of considerable practical importance. A major factor limiting the wider use of these fruitful, and in some cases more disease resistant types, is their small fruit size. The data are suggestive that for size differences alone the hormone sprays combined with vibration practices would be justified for these varieties, although total yields might not be altered.

Many divergences in total yield and average fruit size resulting from treatment and variety in the spring- and fall-grown tomatoes are apparent (Figs. 1, 2). The differences between the yields per plant in the spring and the yields in the fall are remarkable. These variations were apparently caused by the differences in the pattern of solar radiation, since all other environmental variants, including temperatures, were similar. Values for solar radiation, by days, for 1947 are compared in Fig. 3 with the normal daily values to be expected at East Lansing, Michigan. The critical periods of fruit setting and harvesting for the two crops are super-imposed. A close examination of Fig. 3 shows a

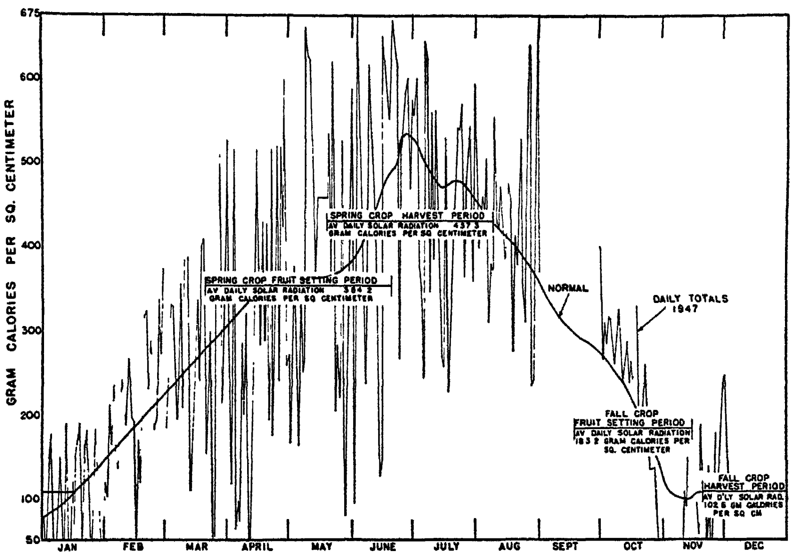


FIG. 3. Daily totals of solar radiation for 1947 and the normal to be expected in East Lansing, Michigan. Critical periods of fruit setting and harvesting for the spring and fall crops are superimposed.

marked difference in the trend of daily solar radiation values during the two periods of fruit development. In the spring fruit-setting period, the radiant values were steadily increasing and had a daily mean of 354.2 gram calories per square centimeter, whereas in the fall the values were steadily decreasing and had a daily mean during the fruit setting period of 183.2 gram calories per square centimeter. The differences during harvest of the two crops were even greater.

It is felt that these variations of solar radiation received by the growing plant are very significant, and though not planned in the original conception of this study, their evaluated effect is of as great significance as the evaluation of the factors for which the study was designed. The amount, and perhaps the pattern, of solar radiation received appears to predetermine the magnitude of fruit harvest. Average yields per plant in the spring, irrespective of variety and treatment, were three times greater than in the fall (Table I). Solar radiation

values for the two crops gave approximately the same divergence (Fig. 3).

Too much emphasis, from a practical standpoint, should not be placed on the results for the fall crop because of the relatively small commercial volume involved compared to that grown in the spring. They are, however, indicative of the importance that environmental differences, particularly those of solar radiation, play in conditioning the normal fruiting response as compared to supplementary fruit setting treatments in greenhouse-grown tomatoes. For the fall crop the progressively shorter photoperiods and days of decreasing light intensities during autumn and early winter provide an environmental reversal of the increasingly longer photoperiods and higher light intensities characteristics of spring crop production. This reversal of solar factors is apparently of sufficient importance to justify further intensive study in the production of crops grown under glass and in the field.

## Summary

Fruit setting treatments consisting of mechanical vibration and hormone sprays were used in growing both a spring and a fall crop of greenhouse tomatoes. In all seven varieties grown in the spring, significant differences were obtained in fruit size, while only American forcing types gave significant yield increases. The nine varieties grown in the fall showed a significant yield response to fruit setting treatments but showed no significant differences in fruit size. The significance of varietal and seasonal responses as they relate to the changing day-to-day pattern of solar radiation is discussed.

## Literature Cited

1. Burk, E. F. The role of pistil length in the development of forcing tomatoes. *Proc. Amer. Soc. Hort. Sci.* 26: 239–240. 1929.
2. Howlett, F. S. The modification of flower structure by environment in varieties of *Lycopersicum esculentum*. *Jour. Agr. Res.* 58: 79–117. 1939.
3. ———— and Marth, P. Aerosol application of growth regulating substances to the greenhouse tomato. *Proc. Amer. Soc. Hort. Sci.* 48: 458–474. 1946.
4. Murneek, A. E. Results of further investigations on the use of "hormone" sprays in tomato culture. *Proc. Amer. Soc. Hort. Sci.* 50: 254–262. 1947.
5. Nylund, R. E. "Hormones" tested on greenhouse tomatoes. *Minn. Horticulturist* 74: 39. 1946.
6. Schneck, H. W. Pollination of greenhouse tomatoes. *N. Y. Agr. Exp. Sta. Bul.* 470. 1928.
7. Strong, M. C. Use of 2,4-dichlorophenoxyacetic acid for the improvement of greenhouse tomato production. *Mich. Agr. Exp. Sta. Quart. Bul.* 28: 216–225. 1946.
8. Young, R. E. Personal correspondence. *Mass. (Waltham) Agr. Exp. Sta.* 1948.

# Effect of the Number of Fruit Per Plant on the Yield and Quality of Cucumber Seed

By MELVIN P. ZOBEL and GLEN N. DAVIS, *University of California, Davis, Calif.*

THE general system of seed production in cucumbers is to allow as many fruits as set normally to mature on the vines, the objective, of course, being a maximum yield of cleaned seed per acre. The question arises, particularly in connection with the production of hybrid cucumber seed, to what extent does limiting the number of fruits which mature per plant affect the yield and quality of the seed produced.

The following data, the result of one year's experiment, were collected to try to shed some light on the problem.

## METHODS

Two varieties of cucumbers, Chicago Pickling and Cubit, were selected for the test. Cubit was selected because it represents a trend in variety production — it has a long fruit with a small seed cavity. The plot was designed as a Latin square with each variety in paired rows, so that one row of each would appear in each treatment. Guard rows were planted on the sides and guard plants left at the ends of the plot to furnish equal competition and allow an equal opportunity for pollination of all test plants.

Four treatments were selected arbitrarily. A, three fruits per plant; B, six; C, nine; and D, the maximum number of fruits a plant would set and mature under conditions of natural pollination. The maximum number must be based on the average fruit set per plant since all plants do not mature the same number of fruits under natural conditions. On the plants where the number of fruit was restricted, the first fruits to set were the ones allowed to mature. Excess fruits were removed from the plants two times per week. Fifteen plants were grown in each replication.

The fruits were harvested when fully mature. The seed was extracted, washed and dried. A germination test was run on duplicate 100-seed samples from each plot. There was no separation of plants within plots but seed from each variety and each plot were kept separate. Graphs represent the mean of four replications.

## RESULTS

*Total Yield of Seed:*—It is evident from the data in Fig. 1, Table I, that the seed yield of different varieties under similar growing conditions may vary greatly. However, this has no particular bearing on the problem so is dismissed with this brief mention. Further discussion in the main is limited to within variety comparisons.

In the variety Chicago Pickling, the total yield of seed increased significantly with each increase in number of fruit maturing per plant. The average number of fruit which matured per plant in the D treat-

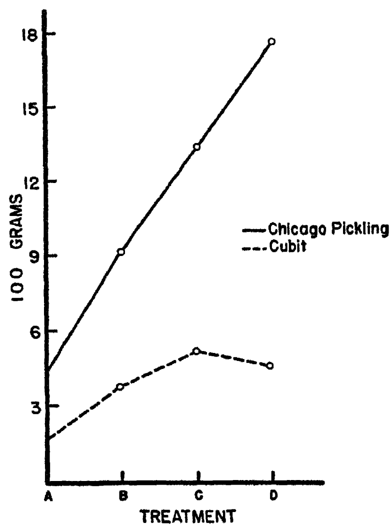


Fig. 1. Total yield of seed.

ment was 12.5. The variety Cubit on the other hand while showing significant increases over the A treatment, in all cases also showed a drop in total seed production between the C and D treatments. This is due to the fact that the number of fruits maturing in both the C and D treatments represent the maximum number of fruits set and matured normally by the plants in the two treatments. Both were below 9 (the figure selected for treatment C). It so happened that in treatment D less fruits matured per plant (6.6) than in treatment C (7.5). Actual yields of seed obtained were used in the calculations.

*Weight of 200 Seeds:*—In calculating the weight of 200 seeds duplicate samples were selected at random from each treatment. As may be noted from Fig. 2, Table II, significant reductions in seed weight were recorded, in both varieties, as the number of fruits matured per plant increased.

TABLE I—Differences in Total Yield of Seed (Grams for the Four Treatments)

| | A | B | C | |
|---|---|---|---|---|
| A | ——— | ——— | ——— | |
| B | 477.8** | ——— | ——— | Chicago Pickling |
| C | 908.8** | 413.0** | ——— | Least sig dif = 125.7 gms* |
| D | 1,329.0** | 851.3** | 420.2** | Least highly sig dif = 190.3 gms** |
| A | ——— | ——— | ——— | |
| B | 205.5* | ——— | ——— | Cubit |
| C | 350.7** | 145.2* | ——— | Least sig dif = 142.8 gms* |
| D | 295.0** | 89.2 | 55.7 | Least highly sig dif = 213.2 gms** |

The production of larger, heavier seed by plants maturing the lesser number of fruits apparently does not affect the quality of the seed. Some investigators have reported results indicating that plants produced from heavier seeds show more vigorous growth, attain greater weight and size, and produce larger yields as determined by number and size of fruits than do plants grown from seeds of lighter weight. On the other hand others have shown by the results of their experiments that the seed weight factor is significant with respect to size of plants only during the early stages of plant growth and that if the growing season is long enough the early superiority might disappear entirely. Oexemann (1) working with soybeans, tomatoes and cucumbers found that with cucumbers the early superiority of plants from the heavier seeds was overcome in about 6 weeks under favorable growing

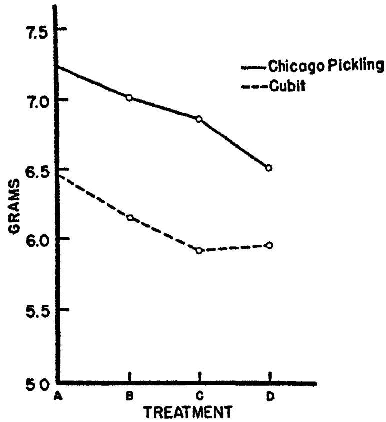


FIG. 2. Weight of 200 seeds.

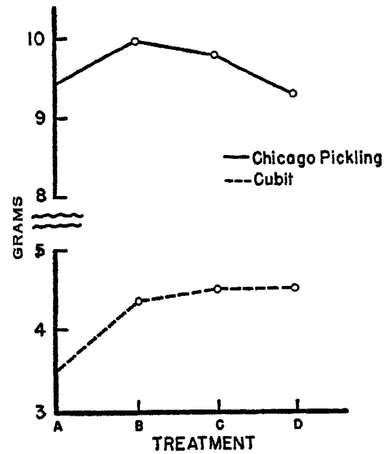


FIG. 3. Yield of seed per fruit, no significant differences.

TABLE II—DIFFERENCES IN WEIGHT OF 200 SEEDS

| | A | B | C | |
|---|---|---|---|---|
| A | — | — | — | |
| B | 0.22* | — | — | Chicago Pickling |
| C | 0.37** | 0.15 | — | Least sig dif = 0.22* |
| D | 0.72** | 0.50** | 0.35** | Least highly sig dif = 0.33** |
| A | — | — | — | |
| B | 0.30* | — | — | Cubit |
| C | 0.53** | 0.23* | — | Least sig dif = 0.22* |
| D | 0.50** | 0.20 | 0.03 | Least highly sig dif = 0.33** |

conditions. There is little relation between seed weight and yield (numbers, sizes and dry weights of fruits and seeds).

Chicago Pickling seed in general was heavier than that of Cubit. When duplicate 200 seed samples were taken from mass seed lots of the two varieties, the weight of 200 seeds of the variety Cubit was 6 ± .5 grams while the weight of a like number of seeds of the variety Chicago Pickling was 7 ± .5 grams.

*Yield of Seed Per Fruit:*—Where yield of seed per fruit was calculated, Fig. 3, the actual yield in the variety Chicago Pickling was highest in treatment B with six fruits per plant and dropped off on each side of this number. However, no significant differences were recorded. In the variety Cubit slight differences were recorded, but here again differences were not significant.

*Seed Germination:*—When germination tests were run on duplicate 100-seed samples from each plot, slight differences were recorded with the lower percentage germination coming in seed harvested from plants maturing the greater number of fruits. No significant differences were recorded in the variety Chicago Pickling.

In the original germination test, significant differences in germination were recorded in the variety Cubit. The seeds which failed to

germinate were stored for 30 days and again tested. Sufficient of tl seed germinated to erase these differences. It is believed the origin: differences were largely due to dormancy as reported by Watts (2)

## Summary

Total yield of cucumber seed was not increased by regulating th number of fruits per plant. Maximum yields were obtained in treat ments where the greatest number of fruits matured.

The quality of cucumber seed was not influenced by regulating th number of fruits which matured per plant.

### Literature Cited

1. Oexemann, Stanley W. Relation of seed weight of vegetative growth, dif ferentiation and yield in plants. *Amer. Jour. Bot.* 29:73–81. 1942.
2. Watts, Victor M. Rest period in cucumber seed. *Proc. Amer. Soc. Hort Sci.* 36:652–654. 1938.

# The Effect of Soil and Climate on the Early and Total Yield of Vegetables Grown at Three Rhode Island Locations[1]

By D. D. DOLAN and E. P. CHRISTOPHER, *Rhode Island State College, Kingston, R. I.*

RHODE ISLAND, though a small state, has considerable variation in climate because of maritime influence. Of the three locations under study, Newport and Kingston, being nearer the ocean, are not so subject to extremes of temperature as is Hillsgrove. On the hottest summer days, the temperature may be 5 to 9 degrees F lower and on the coldest winter days, it may be 7 to 12 degrees F higher at Newport and Kingston than at Hillsgrove. Almost invariably the average annual maximum temperature is higher and the average annual minimum temperature is lower at Hillsgrove than at Newport and Kingston. Because of the maritime influence, there is considerable variation in the frost-free period in different parts of the state. It varies from 120 to 140 days, but it may be 7 to 10 days longer at Newport than at Kingston or Hillsgrove.

Besides showing differences in climatic conditions, the three locations also have distinct soil types. The plantings at Kingston were on Bridgehampton very fine sandy loam. This is a well-drained, well-aerated soil with a medium-high water-holding capacity and is well adapted to nearly all vegetable crops. The soil at Hillsgrove is classified as Merrimac very fine sandy loam, which is similar to Bridgehamton except that the underlying gravel is not so deep and crops suffer more during a protracted drought on this soil than on Bridgehamton soils. The soils of the Newport area are classified as Bernardston loam, which is by far the heaviest of the three soil types and, in addition, has a fairly compact substrate. Both characteristics contribute to its high water-holding capacity and crops on this soil seldom suffer from lack of moisture.

This experiment was designed to study the effects of these variable soil and climatic conditions on the early and total yield of different vegetables and also to determine the comparative adaptability of varieties of these vegetables to the conditions of soil and climate which prevail at the three Rhode Island locations.

## MATERIALS AND METHODS

In the first three years of the experiment, 1943–1945, a number of tomato varieties were grown at each of the three locations. Each year several $F_1$ hybrids, from crosses made at the Rhode Island Agricultural Experiment Station, as well as the regular varieties, were included in the test. In 1945, 16 varieties of cauliflower and in 1946, 15 varieties of cabbage were compared at the three locations.

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[1]Contribution No. 727 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

The 1943 data were secured by R. E. Larsen. Data for the years 1944 and 1945 were secured by E. M. Andersen.

Soil water-holding capacity determinations were obtained through the courtesy of the Department of Agricultural Chemistry.

Each year 1500 pounds of 5–10–5 fertilizer were applied per acr( one-half before and the other half after plowing, the latter disked ir When half grown, each crop was side-dressed with nitrate of soda a 300 pounds per acre. The plants were started in the greenhouse a Kingston and later transplanted to the field at each location. Tomat rows were 4 feet apart with a space of 4 feet between plants in th row. There were 3 feet between rows and 1½ feet between plants i the row in the cabbage and cauliflower plantings. Insecticides used o tomatoes were rotenone and nicotine sulphate sprays. Bordeaux mix ture 2–2–50 and tribasic copper were used to protect the tomato plant from early and late blight. Cabbage plants were protected against mag gots by dusting the roots with calomel at the time of transplantin; Cabbage worms were controlled by dusting the leaves with rotenon during the growing season.

At each harvest, tomato fruits were separated into three grade: No. 1's, No. 2's, and culls. The number and weight of fruits in eac grade were recorded. The total of all pickings up to August 20 con stituted early yield. The total yield was the entire marketable yield, o the sum of No. 1 and No. 2 grades.

Cauliflower and cabbage heads were likewise separated into thre grades, No. 1's, No. 2's and culls; the number and weight of heads i each grade were recorded. The total of the first two cuttings com prised early yield of both cauliflower and cabbage. The sums of No. and No. 2 yields constituted the total marketable yield.

It may be pointed out that the three locations could have been com pared more satisfactorily if the same crop and the same varieties c that crop had been planted annually during the 5-year period. Becaus of changes in personnel, howeve1 the crop grown and the varietie included varied from year to yea1 Even in the first three year: when tomatoes were grown ar nually, the same varieties were nc included. Consequently, in the f nal data, it is impossible to mak comparisons from year to year c to make a combined analysis c variance including all years in th experiment.

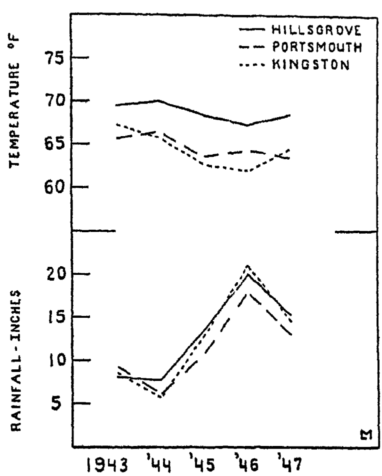



FIG. 1. Total rainfall and average temperature (May 1 to September 1) at three Rhode Island locations.

A graph was constructed ( temperature and rainfall cond tions during the course of the ex periment (Fig. 1). Since there i no weather station at Newpor records from Portsmouth whic is 8 miles removed, were used fc that location. Soil moisture-holc ing capacities were determine and this data supplemented tot:

rainfall in reliably indexing crop moisture supply. Correlation of recorded crop yields with prevailing conditions of temperature, rainfall and soil moisture was attempted.

## Results

The early yields of tomatoes, recorded in Table I, were higher at Hillsgrove than at Newport in all years of the study except in 1945. Total yields, on the other hand, likewise recorded in Table I, are significantly higher at Newport in all three years of the study.

TABLE I—Early and Total Marketable Yield of Tomatoes (Bushel Per Acre) at Three Rhode Island Locations in Three Years

| Year No. | Varieties Included | Harvest | Kingston | Hillsgrove | Newport | Least Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | 19:1 | 99:1 |
| 1943 | 13 | Early | — | 109 | 85 | 23 | 34 |
| | | Total | — | 411 | 761 | 56 | 76 |
| 1944 | 20 | Early | 16 | 61 | 24 | 18 | 23 |
| | | Total | 98 | 150 | 483 | 38 | 49 |
| 1945 | 25 | Early | 12 | 45 | 35 | 14 | 18 |
| | | Total | 109 | 149 | 358 | 51 | 67 |

The 1943 tomato data (Table II) indicate that in early yield, the greenhouse selection 1–43 excelled all varieties except Earliana x Redcap $F_1$. Valiant x Earliana $F_1$ and Waltham Trellis x Earliana $F_1$ are promising early hybrids, producing more than nine of the varieties under test. In all cases, the $F_1$ hybrids gave higher early yields than the regular varieties. Waltham Trellis x Earliana $F_1$ gave a much higher total yield than any other variety.

TABLE II—Average Early and Total Marketable Yields in Bushels Per Acre of 13 Tomato Varieties Grown in 1943 at Two Locations in Rhode Island

| Variety | Source | Yield (Bushels Per Acre) | |
|---|---|---|---|
| | | Early | Total |
| Greenhouse Selection 1–43 | R. I. Agr. Exp. Sta. | 177 | 333 |
| Earliana × Redcap $F_1$ | R. I. Agr. Exp. Sta. | 165 | 622 |
| Valiant × Earliana $F_1$ | R. I. Agr. Exp. Sta. | 140 | 654 |
| Waltham Trellis × Earliana $F_1$ | R. I. Agr. Exp. Sta. | 119 | 727 |
| Valiant | Stokes | 92 | 630 |
| Redcap | Woodruff | 83 | 655 |
| Scarlet Dawn | Woodruff | 82 | 557 |
| Comet | Samuel Smith Co., New York | 81 | 489 |
| Waltham Trellis | Boston Market Gardeners | 63 | 547 |
| Bestal | Ottawa OE259 | 60 | 657 |
| Stokesdale | Stokes | 59 | 651 |
| Marglobe | Stokes | 57 | 563 |
| Rutgers | Stokes | 28 | 534 |
| Least difference 19:1 | | 25 | 15 |
| 99:1 | | 34 | 20 |

The 1944 tomato data (Table III) show that the two $F_1$ hybrids, Earliana x Redcap $F_1$ and Valiant x Earliana $F_1$ excelled all the regular varieties in early yield except Red Cloud and Earliana. Both Red Cloud and Earliana gave higher early yields than 8 of the varieties under test. Differences in total marketable yield were not significant.

The 1945 tomato data (Table IV) show that in early yield Valiant x Earliana $F_1$ and Red Cloud exceeded all varieties under test except

TABLE III—AVERAGE EARLY AND TOTAL MARKETABLE YIELDS IN BUSHELS PER ACRE OF 20 TOMATO VARIETIES GROWN IN 1944 AT THREE LOCATIONS IN RHODE ISLAND

| Variety | Source | Yield (Bushels Per Acre) | |
|---|---|---|---|
| | | Early | Total |
| Earliana × Redcap $F_1$ | R. I. Agr. Exp. Sta. | 68 | 279 |
| Valiant × Earliana $F_1$ | R. I. Agr. Exp. Sta. | 64 | 304 |
| Red Cloud | Nebraska | 57 | 188 |
| Earliana | Burpee | 53 | 176 |
| Valiant | Stokes | 42 | 225 |
| Sioux | Nebraska | 40 | 208 |
| Bestal | Ottawa OE259 | 38 | 238 |
| Coventry | Storrs | 37 | 276 |
| Vetomold | Vineland, Ontario | 32 | 337 |
| Comet | Harris | 32 | 229 |
| Stokesdale | Stokes | 31 | 276 |
| Scarlet Dawn | Asgrow | 31 | 236 |
| Vetomold 121 | Vineland, Ontario | 27 | 259 |
| Wasatch Beauty | Gill Brothers | 22 | 168 |
| Pritchard | Burpee | 21 | 237 |
| Rutgers | Stokes | 19 | 225 |
| Master Marglobe | Stokes | 18 | 307 |
| Pan America | Burpee | 16 | 254 |
| Michigan Hybrid | Grand Rapids, Michigan | 13 | 234 |
| Michigan State Forcing | Grand Rapids, Michigan | 12 | 218 |
| Least difference 19:1 | | 24 | Differences are not significant |
| 99:1 | | 32 | |

Pennheart, Early Chatham and Earliana. These three in turn exceeded 11 of the varieties in early yield. In total yield, Valiant Earliana $F_1$, Pritchard, Sioux, Wasatch Beauty and Redcap were not significantly different and all gave higher yields than 12 well-known commercial varieties.

TABLE IV—AVERAGE EARLY AND TOTAL MARKETABLE YIELDS IN BUSHELS PER ACRE OF 25 TOMATO VARIETIES GROWN IN 1945 AT THREE LOCATIONS IN RHODE ISLAND

| Variety | Source | Yield (Bushels Per Acre) | |
|---|---|---|---|
| | | Early | Total |
| Valiant × Earliana $F_1$ | R. I. Agr. Exp. Sta. | 79 | 289 |
| Red Cloud | Northrup King | 69 | 202 |
| Pennheart | Eastern States | 57 | 227 |
| Early Chatham | N. H. Agr. Exp. Sta. | 56 | 174 |
| Earliana | Burpee | 54 | 244 |
| Sioux | Northrup King | 44 | 280 |
| Valiant | Stokes | 40 | 196 |
| Bestal | Ottawa | 34 | 214 |
| Suttons Best of All | Dupuy and Ferguson | 34 | 179 |
| Wasatch Beauty | Gill Brothers | 30 | 281 |
| Redcap | Woodruff | 29 | 278 |
| Victor | Harris | 27 | 138 |
| Comet | Harris | 26 | 218 |
| Pritchard | Burpee | 26 | 282 |
| Stokesdale | Stokes | 25 | 211 |
| Vetomold | Vineland, Ontario | 24 | 243 |
| Bounty | Burpee | 22 | 116 |
| Vetomold 121 | Vineland, Ontario | 18 | 174 |
| Marglobe | Stokes | 15 | 171 |
| Scarlet Dawn | Associated | 15 | 190 |
| Bonny Best | Burpee | 13 | 204 |
| Coventry | Conn. Agr. Exp. Sta. | 10 | 193 |
| Rutgers | Stokes | 8 | 158 |
| Michigan State Forcing | Grand Rapids, Michigan | 5 | 83 |
| Pan America | Associated | 5 | 153 |
| Least difference 19:1 | | 30 | 80 |
| 99:1 | | 41 | 107 |

As shown in Table V, an early planting of cauliflower produced higher early yields at both Kingston and Hillsgrove than at Newport. On the other hand, a late planting of cauliflower in the same year gave significantly higher yields at Newport than at Kingston and the Hillsgrove crop was a failure because of drought.

TABLE V—EARLY AND TOTAL MARKETABLE YIELD OF CAULIFLOWER IN HUNDREDWEIGHT PER ACRE AT THREE RHODE ISLAND LOCATIONS IN BOTH AN EARLY AND LATE PLANTING IN 1946

| Planting | No. Varieties Included | Harvest | Kingston | Hillsgrove | Newport | Least Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | 19:1 | 99:1 |
| Early | 16 | Early | 40 | 36 | 24 | 8 | 11 |
| | | Total | 113 | 96 | 75 | 16 | 22 |
| Late | 16 | Early | 26 | — | 40 | 11 | 15 |
| | | Total | 84 | — | 105 | 17 | 23 |

Cauliflower varietal comparisons in 1946 (Table VI) ranked the Super Snowball strains highest in early yield, while Holland Erfurt and Danish Early led in total yield. Heads of the two latter varieties were heavier than those of several varieties under test.

TABLE VI—EARLY AND TOTAL YIELDS IN HUNDREDWEIGHT PER ACRE AND WEIGHT IN POUNDS PER HEAD OF 16 VARIETIES OF CAULIFLOWER GROWN IN 1946

| Variety | Source | Yield (Hundredweight Per Acre) | | Pounds Per Head |
|---|---|---|---|---|
| | | Early | Total | |
| Super Snowball | Eastern States | 76.7 | 119.8 | 2.54 |
| Super Snowball | Harris | 50.9 | 103.3 | 2.45 |
| Super Snowball | Associated | 49.6 | 92.8 | 2.37 |
| Danish Early | Eastern States | 44.1 | 131.7 | 2.96 |
| Improved Super Snowball | Burpee | 42.8 | 110.4 | 2.25 |
| Holland Erfurt | Eastern States | 38.3 | 135.9 | 2.89 |
| Burpeana | Burpee | 37.4 | 102.2 | 2.40 |
| Improved Holland Erfurt | Burpee | 32.7 | 104.3 | 2.84 |
| New Early Purple Head | Harris | 32.0 | 65.1 | 1.59 |
| Super Snowball | Woodruff | 31.5 | 91.9 | 2.28 |
| Dry Weather | Burpee | 25.1 | 104.8 | 2.57 |
| Early Snowball | Associated | 21.4 | 95.9 | 2.70 |
| Early Snowball | Woodruff | 18.2 | 96.4 | 2.73 |
| Snowball | Harris | 12.5 | 85.4 | 2.85 |
| Snowdrift | Woodruff | 12.4 | 58.7 | 2.84 |
| Veitch's Autumn Giant | Burpee | 2.0 | 12.8 | 1.40 |
| Least difference: 19:1 | | 28.0 | 11.8 | 0.66 |
| 99:1 | | 37.7 | 15.6 | 0.87 |

Yields of the late cabbage planting (Table VII) at the three locations compare very well with yields of the late cauliflower planting of the previous year. Early yields in the late cabbage planting were higher at Newport than at either of the other locations. Total yields at Newport were significantly higher than at Hillsgrove but not significantly higher than at Kingston.

The cabbage varietal comparisons made in 1947 (Table VIII) indicate that Early Cortland gave significantly higher early yield than 10 of the varieties tested. Green Acre, Copenhagen Market, Golden Acre and Light Glory have merit as early market varieties. In total yield, Light Glory greatly outranked all other varieties. Glory of Enk-

TABLE VII—EARLY AND TOTAL MARKETABLE YIELD OF CABBAGE IN HUNDREDWEIGHT PER ACRE AT THREE RHODE ISLAND LOCATIONS IN A LATE PLANTING IN 1947

| No. Varieties Included | Harvest | Kingston | Hillsgrove | Newport | Least Difference | |
|---|---|---|---|---|---|---|
| | | | | | 19:1 | 99:1 |
| 15 | Early | 203 | 187 | 216 | 13 | 18 |
| | Total | 257 | 231 | 270 | 17 | 23 |

huizen and Green Acre yielded higher than nine others. The heads of Light Glory were much heavier than those of any other variety. Glory of Enkhuizen, Copenhagen Market, Early Cortland, Green Acre and Golden Acre, all ranked high in weight per head.

TABLE VIII—EARLY AND TOTAL YIELDS IN HUNDREDWEIGHT PER ACRE AND WEIGHT IN POUNDS PER HEAD OF 15 VARIETIES OF CABBAGE GROWN IN 1947

| Variety | Source | Yield (Hundredweight Per Acre) | | Pounds Per Head |
|---|---|---|---|---|
| | | Early | Total | |
| Early Cortland | Reed Brothers | 283.8 | 290.7 | 3.58 |
| Green Acre | Woodruff | 272.6 | 304.7 | 3.54 |
| Copenhagen Market | Woodruff | 272.2 | 284.2 | 3.67 |
| Golden Acre | Eastern States | 266.8 | 274.1 | 3.48 |
| Light Glory | Cornell | 264.8 | 379.1 | 4.64 |
| Glory of Enkhuizen | Woodruff | 249.7 | 305.8 | 3.78 |
| Marion Market | Eastern States | 245.1 | 285.4 | 3.55 |
| Early Jersey Wakefield | Woodruff | 234.6 | 246.6 | 2.91 |
| Early Danish Type | Cornell | 227.8 | 249.4 | 3.01 |
| Early Round Dutch | Associated | 198.6 | 223.4 | 2.85 |
| Jersey Queen × Golden Acre $F_4$ | Cornell | 159.5 | 184.3 | 2.68 |
| All Head Early | Woodruff | 131.6 | 243.5 | 3.39 |
| Cornell Early Danish | Cornell | 92.9 | 169.6 | 2.22 |
| All Seasons | Woodruff | 79.8 | 187.7 | 3.19 |
| Drumhead Savoy | Eastern States | 50.3 | 159.4 | 2.26 |
| Least difference 19:1 | | 29.8 | 31.8 | |
| 99:1 | | 39.5 | 42.1 | |

## OBSERVATIONS AND DISCUSSION

The average temperature from May 1 to September 1 is 3.5 to 4.0 degrees F higher at Hillsgrove than at either of the other locations (Fig. 1). This, together with lighter soil type, may account for the higher early yields of tomatoes and cauliflower at the Hillsgrove location. The lower average temperatures at Portsmouth and Kingston may partially account for the higher yields from late plantings of cabbage and cauliflower at these locations. The difference in average temperature between Portsmouth and Kingston, although fairly consistent, is probably too slight to account for differences in yield.

Differences in rainfall at the three locations although somewhat consistent were not very pronounced (Fig. 1) and are probably not responsible for yield variations from one location to another. This does not mean, however, that moisture was available to the vegetable crops to the same degree at all three locations. There was great variation in the moisture-holding capacity of the soils at the different loca-

tions (Table IX) and it seems that of all environmental factors, this one had the greatest influence on crop yields.

There is a striking correlation between the moisture-holding capacity of the soil and total yield, particularly in the dry years 1944 and 1946.

TABLE IX—MOISTURE-HOLDING CAPACITY OF SOILS AT THREE RHODE ISLAND LOCATIONS EXPRESSED AS A PERCENTAGE OF THE OVEN-DRY SOIL WEIGHT*

| Year | Location | | |
|---|---|---|---|
| | Kingston | Hillsgrove | Newport |
| 1944 | 58 | 38 | 61 |
| 1945 | 56 | 43 | 63 |
| 1946 | 65 | 40 | 52 |
| 1947 | 66 | 42 | 55 |

*While the soil type remained the same in each location, the actual plot of land used varied and this accounts for the yearly fluctuations.

In these years drought definitely decreased yields on soils of low moisture-holding capacity. In 1946 during the protracted July drought, the cauliflower crop at Newport flourished and produced very favorable yields, while the crops at the other two locations suffered from drought. The Hillsgrove planting was so severely affected that many of the plants died and it was decided not to take yield records at this location. The dry weather also seemed to favor the appearance of boron-deficiency symptoms in the cauliflower crop; the disease caused more damage in the Kingston than the Newport planting.

In 1944, tomato total yields at Kingston were significantly lower than at either of the other locations; in 1945 they were significantly lower at Kingston than at Newport. This may be partially explained by the occurrence of a malady in all years at Kingston and not at the other locations. This malady displays itself as a sloughing off of the root tips and is thought to be due to a soil-inhabiting fungus. Although no permanent remedy is known, it has been demonstrated that the condition can be prevented for one season by treating the soil with chlorpicrin at the rate of approximately 300 pounds per acre previous to planting.

## SUMMARY AND CONCLUSIONS

In two out of the three years when tomatoes were grown, the early yields were higher at Hillsgrove than at either of the two other locations. This was thought to be due to the higher average temperature and the lighter soil at Hillsgrove.

The total yield of tomatoes in all three years, late cauliflower in 1946 and late cabbage in 1947, were higher at Newport than at either of the other locations. This was shown to be due mainly to the greater water-retaining capacity of the Bernardston loam of the Newport area, but partially to the occurrence of a tomato malady at Kingston. Differences in total yield at the three locations cannot be explained by differences in total rainfall.

Varieties of tomatoes giving the highest early yields were Earliana x Redcap $F_1$, Valiant x Earliana $F_1$, Waltham Trellis x Earliana $F_1$, Earliana and Red Cloud. In total yield Waltham Trellis x Earliana $F_1$,

Valiant x Earliana $F_1$, Pritchard, Sioux, Wasatch Beauty and Redcap were outstanding.

Cauliflower varietal comparisons ranked the Super Snowball strains highest in early yield, while Holland Erfurt and Danish Early led in total yield. The latter two varieties also displayed the highest average weight per head.

Of the cabbage varieties compared, Early Cortland outranked all others in early yield. Green Acre, Copenhagen Market, Golden Acre and Light Glory also have considerable merit as early market varieties. In total yield, Light Glory was the highest and had the heaviest heads. Glory of Enkhuizen and Green Acre was also high in total yield.

The results of this study are fairly consistent from year to year. This is particularly evident in the tomato data which were accumulated in three consecutive years. This study illustrates well that soil and climatic conditions may vary greatly in a relatively small area and this in turn markedly effects the yield of three vegetable crops.

# Vegetative Propagation of Short-Day Varieties of Onions As an Aid in a Breeding Program

By H. A. Jones, *Plant Industry Station, Beltsville, Md.*, B. A. Perry, *Texas Agricultural Experiment Station, Winter Haven, Tex.*, and W. C. Edmundson, *Greeley, Colo.*

A cooperative onion-breeding program between the Texas Agricultural Experiment Station and the United States Department of Agriculture has been in operation since early in 1940. The chief object of this cooperation has been to develop Bermuda-type onions that are adapted to southern Texas, are early, are resistant to thrips and pink root, and are less prone to bolt and split than are the older strains.

In this breeding program it has been found essential to make selections in the area in which the bulb crop is to be grown commercially. Selections cannot be made successfully in the North where the plants grow and mature under a different set of climatic conditions. A variety like Excel will mature early in the North, and the bulbs will be exceptionally small; but like most varieties it is not homozygous for time of maturity and some plants will mature late and make better size, and for this reason will usually be selected. Late-maturing bulbs selected in the North will definitely make late-maturing strains when planted in the South. For southern Texas, especially, we are interested in producing extra early strains, and this can be done best by selecting in the South.

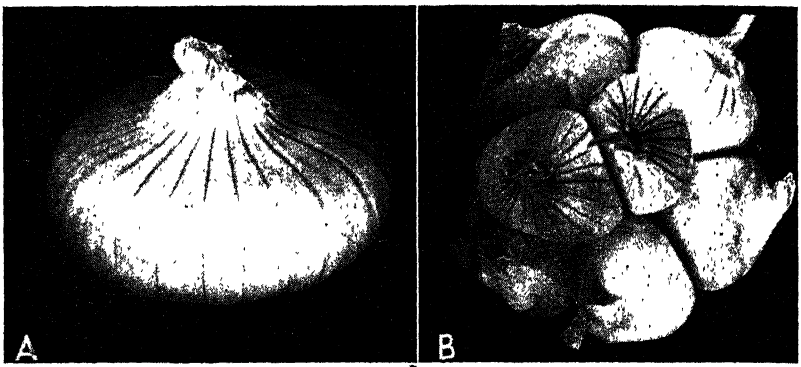
Most of the crossing and selfing has been done at Beltsville, Maryland. Seed has been increased in the West, and the progenies have been tested in several locations in southern Texas. Selections made in Texas in early spring need to be maintained until the following fall, winter, or early spring, depending upon where they are to be planted for seed production. As the Bermuda and Grano varieties are only fair keepers, many selections may be lost because of rots and sprouting. To avoid these losses the method described here was developed to maintain the selections vegetatively until such time as they could be planted for seed production.

## Procedure

Bulbs are selected in southern Texas when the crop matures, in late March or early April. These are well cured and then shipped to Greeley, Colorado about May 1. At Greeley the bulbs are placed in shallow trays and kept in a well-ventilated shed until about the middle of July. At this time most of the selections have completed their rest period, as is indicated by protrusion of the root primordia at the stem plate. The bulbs are now set in the field in shallow furrows on top of beds the same as those used for the growing of carrots and lettuce under irrigation. The bulbs are covered lightly with soil and sufficient water is then run into the furrows between the beds to bring the moisture to the base of the bulb. The bulbs should start to grow as soon as water is applied. If the bulbs are planted and watered before the end of the rest period there is danger of loss from rot. Because of high tempera-

tures flooding at this time is disastrous. The growing plant forms a number of shoots which arise from buds in the axils of the bulb scales.

Flower stems and flower primordia are not formed because temperatures are too high. The combination of high temperatures and long days favor early bulbing and quick maturity in short-day varieties. Each shoot develops a bulb at the base, thus each mother plant forms a cluster of bulbs (Fig. 1).



A B

FIG. 1. *A*, Yellow Bermuda bulb before planting for vegetative increase. *B*, Yellow Bermuda bulb after vegetative increase. A and B are not photographed to the same scale.

Usually four to seven bulbs are formed from one mother plant. About the middle of September the bulbs begin to mature. As soon as the tops fall and begin to turn yellow the plants are harvested, topped, and placed in shallow trays in a cool, well-ventilated place. Moisture may accumulate between the bulbs in the cluster making an ideal place for rots to start. For this reason the cluster should be separated at the base either by cutting or breaking, care being taken not to injure the scales. The bulbs are usually through the rest period by December 1, but with proper storage they can be held in good condition for planting until early the following spring.

Only sufficient data will be presented here to show a few of the results obtained. With some variation this same procedure has been followed since about 1940. At first an attempt was made to increase the selections vegetatively at Beltsville. The plants divided and bulbed satisfactorily, but considerable rotting occurred. Much better results have been obtained under the dry atmospheric conditions that exist at Greeley. No doubt just as good results could be had in other places where the proper temperature, humidity, and length-of-day conditions prevail.

## RESULTS

In the spring of 1947, 52 lots of onions were selected in southern Texas. The quantity in each lot varied from 1 bulb to 1½ bushels.

These were increased vegetatively at Greeley. Bulbs that were to be planted for selfing, crossing, and a few for seed increase were sent to Beltsville and planted in the greenhouse in December. One lot, Laredo 36, after vegetative increase had about 450 bulbs. These were planted in a section of a screened greenhouse where honey bees were used to do the pollinating. A total of 5 pounds 2 ounces of seed was harvested. Other lots were sent to Davis, California, for late fall planting. The seed crop there was curtailed because of a severe attack of mildew. Still other increase lots were held in storage at Greeley during the winter and shipped to Caldwell, Idaho in March. The plantings in Idaho were made about 11 months after the original bulbs were selected in Texas. Maintaining the original bulbs for this long a time would have been impossible. A good yield of seed was obtained.

In the spring of 1948 about 250 lots were selected in southern Texas and shipped to Greeley for vegetative increase. The number of bulbs in the different lots varied from 1 to 170. Just before planting on July 12 a number of the lots were weighed and the data are recorded in Table I. At time of harvest, October 5, the lots were weighed again.

TABLE I—INCREASE IN WEIGHT OF TEXAS EARLY GRANO AND BERMUDA-TYPE ONIONS WHEN GROWN VEGETATIVELY AT GREELEY, COLORADO, JULY TO OCTOBER 1948

| Lot No. | Type or Variety | Bulbs Planted July 12 | | Bulb Clusters Harvested Oct 5 | | Increase in Weight (Per Cent) |
|---|---|---|---|---|---|---|
| | | Number | Weight (Lbs) | Number | Weight (Lbs) | |
| CC 44* | Crystal Wax | 22 | 4.00 | 21 | 10.00 | 150 |
| CC 48 | Crystal Wax | 22 | 3.25 | 16 | 7.50 | 131 |
| CC 49 | Crystal Wax | 20 | 3.25 | 18 | 12.75 | 392 |
| CC 63 | Crystal Wax | 30 | 5.25 | 29 | 17.00 | 238 |
| CC 76 | Crystal Wax | 24 | 4.00 | 22 | 9.75 | 144 |
| CC 83 | Crystal Wax | 22 | 3.50 | 20 | 11.00 | 214 |
| CC 160 | Crystal Wax | 35 | 5.25 | 31 | 13.00 | 148 |
| CC 163 | Crystal Wax | 26 | 4.75 | 26 | 11.50 | 142 |
| CC 250 | Yellow Bermuda | 170 | 17.75 | 165 | 63.00 | 255 |
| CC 330 | Yellow Bermuda | 29 | 3.75 | 26 | 10.00 | 167 |
| CC 331 | Yellow Bermuda | 30 | 4.00 | 30 | 11.00 | 175 |
| WH 408** | Texas Early Grano (glossy) | 18 | 4.00 | 11 | 5.25 | 31 |
| WH 413 | Yellow Bermuda (glossy) | 76 | 16.25 | 36 | 17.00† | 5 |
| WH 420 | Texas Early Grano 502 | 45 | 21.00 | 43 | 41.50 | 98 |

*CC = Crystal City.
**WH = Winter Haven.
†Not harvested till October 14.

The increase in weight varied from 5 to 392 per cent. W H 413 was slow to start growing after planting on July 12, which indicated that it had not completed the rest period. It was slow to start bulbing and some of the bulbs had not matured and had to be discarded at the time of harvest on October 14. This indicates that varieties or selections that are to be increased vegetatively at Greeley or at a similar location must have a short rest period and be early maturing.

## SUMMARY

A procedure is described for maintaining and increasing vegetatively short-day varieties of onions that have a short rest period. Varieties

like Yellow Bermuda, Crystal Wax, and Texas Early Grano 502, which bulb under a short photoperiod, are harvested in Texas in late March or early April. These are cured, shipped to Colorado, stored until about July 15, and then planted. The resulting plants form several branches, and under conditions of high temperature and long days a cluster of bulbs is formed. These can be stored for several months, or until such time as they can be planted in the greenhouse or field for seed production.

# A Preliminary Report on the Yield and Oil Content of Clonal Strains of Garden Sage

By Brooks D. Drain, J. P. Overcash,[1] R. H. Hanchey[2] and A. H. Downey,[3] *University of Tennessee, Knoxville, Tenn.*

The United States, previous to 1940, normally imported about 1,500,000 pounds of sage as dried leaves. Some garden sage, *Salvia officinalis,* was grown in this country during the war period, while the European supply was cut off. Early plantings at the Tennessee Station were vegetative and produced very little seed. An oil assay of a seedling population gave a value of 1.14 per cent sage oil on an air dry basis for leaves and tender stems. Guenther (1) reports an average assay of 1.40 per cent oil for stemless Dalmation sage varying with quality and time of harvest. Greek, French and Spanish sage

Fig. 1. A garden sage planting of seedling plants at the West Tennessee Station. Superior plants vegetatively and of high oil content have been selected from such plantings.

assay somewhat lower. This suggested that the United States grower would need improved strains, and mechanized production, if he were to compete with the European crop. The Tennessee Agricultural Experiment Station made a report (2) on the propagation and culture of this plant in 1945. Some vegetative clonal strains were isolated and propagated (3). Two plots of each strain 28 feet long, plants 2 feet

[1]Resigned September 30, 1945.
[2]Resigned December 31, 1946.
[3]With Magnus, Mabee & Reynard, Inc., made the oil assays.

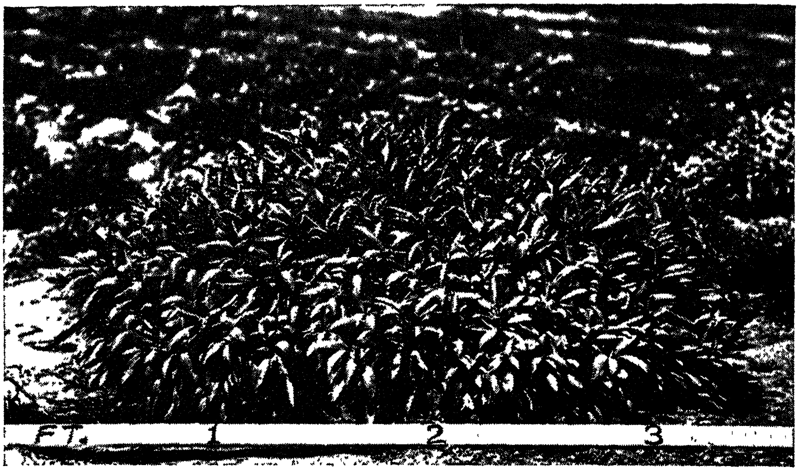


FIG. 2. A single plant of sage. Clonal strains are propagated vegetatively from a single superior plant.

apart in the row and 3 feet between rows were available for taking yield records. A controlled random arrangement was used. Assay samples were taken from all 28 plants of a given strain, and from cuttings as noted below. Assays made in later years indicated the importance of time of cutting on oil content, but this was not known to the writers when these samples were taken. However the assays are comparable within a given season, and data on yield and oil content of 14 clonal strains are presented in Table I. These strains had been selected for desirable leaf and plant characters, but were random selections for assaying.

The 1945 assay samples were cut July 7, August 24 and September 26 with one-quarter of the sample taken at each of the first two cuttings and one-half at the third. Leaves and tender stems were gathered and the samples dried in the shade by drawing air over them using an electric fan. The air dry leaves and stems were carefully mixed and a sample taken for assaying on an air dry basis. The 1946 samples were managed in the same way except that only an April 15 cutting was used. The later set of samples average 1.30 per cent sage oil and the former 1.14. In 1946, the plants were 1 year older and seasonal variations may help to account for some of the differences. Tennessee clonal strain No. 5 had the highest oil content, although strain No. 8 have a somewhat larger yield of oil per acre.

Assays were made of samples taken from different dates of harvest of clonal strains No. 5 and No. 15. The per cent of sage oil was calculated on an air-dry basis. These data, presented in Table II, indicate that environmental factors have an important influence on oil content and that samples for assaying should be taken at the same time and under uniform conditions. This will help to explain some of the variations noted in Table I. The first and last cuttings each season

TABLE I—YIELD OF LEAVES AND YOUNG STEM AND OIL CONTENT OF GARDEN SAGE AT JACKSON, TENNESSEE

| No. Tennessee Clonal Strain | Yield of Leaves and Stems Per Acre 1945* (Lbs) | Oil Assays (Per Cent) | |
|---|---|---|---|
| | | 1945* | 1946** |
| 1 | 1,942 | 1.40 | 1.50 |
| 2 | 2,048 | 0.90 | 1.60 |
| 3 | 1,348 | 0.90 | 1.40 |
| 4 | 2,168 | 1.20 | 1.60 |
| 5 | 2,076 | 1.60 | 1.60 |
| 6 | 346 | 1.40 | — |
| 7 | 2,004 | 1.00 | 1.80 |
| 8 | 2,492 | 1.40 | 1.40 |
| 9 | 1,366 | 1.10 | 1.50 |
| 10 | 852 | 1.00 | 1.00 |
| 11 | 2,829 | 0.90 | 1 01 |
| 12 | 2,170 | 1.20 | 1.03 |
| 13 | 2,048 | 1.00 | 0.55 |
| 14 | 1,879 | 1.00 | 1.42 |
| 15 | 2,406 | 1.10 | 1.20 |

*Cut July 7, August 24 and September 26, all samples air dried.
**April 15 cutting only.

tend to have a lower oil content than the midsummer cuttings. Strain No. 5 assayed higher in oil content throughout the season than strain No. 15 and suggests that a genetic factor also influences oil content.

Table III presents some data on variations in oil content among individual plants within a given clonal strain. The two strains are not

TABLE II—OIL CONTENT OF GARDEN SAGE WITHIN TWO CLONAL STRAINS AT VARIOUS DATES OF CUTTING

| Tennessee Clonal Strain | Harvesting Date* (Per Cent) | | | | |
|---|---|---|---|---|---|
| | Apr 15 | May 17 | Jun 19 | Jul 30 | Sep 26 |
| No. 5 | 1.60 | 2.10 | 3.00 | 3.25 | 2.69 |
| No. 15 | 1.20 | 1.68 | 1.75 | 1.25 | 0.60 |

*A 2-pound sample green weight was used in most cases from which a 200-gram sample air-dry was taken for assaying.

TABLE III—VARIATIONS IN SAGE OIL WITHIN TWO CLONAL STRAINS EXPRESSED AS PER CENT BY WEIGHT OF AIR DRY LEAVES AND YOUNG STEMS

| Tennessee Clonal Strain | Assays of Sage Oil From Individual Plants | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. 24 | No. 25 | No. 26 | No. 27 | No. 28 | No. 29 | No. 30 | No. 31 | No. 32 |
| No. 5* | 2.28 | 2.60 | 2.71 | 2.65 | — | — | — | — | — |
| No. 15** | — | — | — | — | 1.55 | 1.65 | 1.09 | 1.21 | 1.25 |

*Harvested May 17, June 19, July 30, and September 26.
**Harvested May 17, June 19, and July 30.

comparable in these data as strain No. 5 was cut four times and No. 15 three. There are some differences among individual plants although all plants of the former strain assayed high and all of the latter low. These plants were growing in replicated plots and on land selected for uniformity. Cultural treatments, harvesting and drying were uniform.

These studies indicate that both environmental and genetic factors

influence sage oil content. If environmental factors are made as uniform as possible, high-oil assaying clonal strains of garden sage could be selected.

## Literature Cited

1. Guenther, E. S. Survey of dalamation essential oils. *Amer. Perfumer and Essential Oil Rev.* Oct.-Nov. 1933.
2. Overcash, J. P. Propagation and culture of garden sage in Tennessee. *Proc. Amer. Soc. Hort. Sci.* 46: 345–349. 1945.
3. Overcash, J. P., and Drain, Brooks D. *Tenn. Agr. Exp. Sta. Ann. Rep.* 38: 126–127. 1945.

# Some Effects of Repeated Applications of Manures and Fertilizers on the Organic, Nitrate, and Moisture Content of the Soil and on the Yield of Truck Crops

By L. M. WARE and W. A. JOHNSON, *Alabama Agricultural Experiment Station, Auburn, Ala.*

THE organic content of the soil has long been associated with productivity of land (1, 2, 3). To a large degree this may be attributed to the close relation of soil nitrogen to soil organic matter. Studies of the organic and nitrogen contents of soils in the several regions of the nation have revealed that the organic matter and nitrogen in soils decrease from North to South (1, 2, 3). The low organic content and the low nitrogen content of southern soils have long been recognized. The difficulty of increasing or even maintaining the organic content of soils in the South has likewise been recognized (3).

On some soils of the South, it is difficult to obtain satisfactory yields of certain vegetable crops by applications even of large amounts of commercial fertilizers without the addition also of organic material. Animal manures are especially effective in increasing yields on these soils (4). Legumes are only partly effective in increasing yields on some soils, especially in the spring.

This study was undertaken to determine the effects of repeated applications of different kinds of manures and different rates of fertilizers on the organic content of the soil, soil moisture, available soil nitrogen, and yields of spring and fall crops.

## METHODS

The studies were conducted on a sandy loam soil of relatively low fertility belonging to the Chesterfield series. Organic matter and nitrogen were quite low in the soil. Concrete field bins 1/320 acre in size were used. The topsoil for a depth of 10 inches in the complete series was intermixed, thoroughly composited, and distributed equally among the bins before the experiment was started. The composited topsoil was placed on the undisturbed subsoil. Treatments were quadruplicated and arranged in a 4-block randomized design. Four different crops were grown per bin in single-row plots in the spring and four others were grown in the fall.

The treatments consisted of progressively more intensive practices. The rates of fertilizer applications were 0, 1,000, 1,500, and 2,000 pounds per acre of a 6-10-6 analysis. The indicated amounts were added both to the spring crop and to the fall crop. The rates of application of manure were 0, 6, 12, and 18 tons per acre applied once per year. The high rates of fertilizer and the high rates of manure were always associated, as well as the intermediate and low rates of fertilizers and manures except for the 0 rate of manure. With each rate of fertilizer receiving a manure, there was one treatment with a legume turned under, one with a nonlegume turned under, and one

with a nonlegume grown and removed. There were seven treatments without animal manure. Three treatments consisted of the three rates of applied fertilizer with a legume turned under, and three consisted of the three rates of applied fertilizer with a nonlegume removed. There was one treatment receiving no animal manure, no commercial fertilizer, and no green manure.

The phenoldisulphonic acid method was used for nitrate determinations, the chromic acid reduction method for organic matter and the oven-dry method for moisture. Soil samples represent a composite of eight borings from each bin. Samples for nitrates and moisture were taken at 2- to 3-week intervals during the growing season and for organic matter once annually.

The experiment was started in 1940 and continued without change through 1947.

## Presentation of Data

Because of the interrelation of soil treatments and the resulting effects on the soil and crop yield, the data have been grouped into tables permitting intercomparisons. For ease of interpretation, the treatments in general have been arranged in the table in the order of their effects on the organic content, soil moisture, available soil nitrogen, and crop yields, ranging from high to low. This is referred to as the base order of treatments. For each effect measured—organic content, soil nitrate, soil moisture, and the yield of each crop—the relative order from high to low as well as the actual quantities is indicated in the table for each of the treatments given.

Animal manure, in general, exerted the greatest effect on the soil and on yields. Treatments in the table have, therefore, been arranged in descending order from 18, 12, 6, and 0 tons per acre of animal manure. Within each of the rates of application of animal manure, the green manures were arranged in order of legumes turned under, nonlegumes turned under, and nonlegumes removed. The base order of treatments has been numbered from 1 to 16, the lowest number corresponding to the treatment generally exerting the greatest effect.

An analysis of variance was made and the least significant difference determined for each set of effects measured. The least significant difference for each measured effect is indicated under the column for that effect.

## Effects of Fertilizers and Organic Treatments on Soil Organic Matter

It may be noted in Table I that the order in which the percentages of organic matter fell corresponded almost exactly with the base order of treatments (columns 6 and 7). The only exception to the perfect agreement in the order of the two columns occurred where differences were below the .05 level of significance. For instance, in column 7 the percentage of organic matter for the treatment corresponding to the base order of 10, actually was in position 11, and the percentage for the treatment corresponding to the base order of 11 was in position 10. A similar exchange occurred in the order of treatment in positions 13,

14, and 15. The differences, however, in the percentage of organic matter in the plots corresponding to the treatments in the exchanged positions was only .01 per cent, whereas a difference of .04 is required for significance.

The organic matter in the soil used in this study was very low. The organic content of the check plot receiving no organic treatment averaged .37 per cent over the 6-year period 1941 to 1946, inclusive. The amount did not vary appreciably during the experiment. Repeated applications of animal manure and the turning under of green manures did not give a soil of high organic content, although the percentage of organic matter was doubled by some treatments during the 6 years. Plots receiving 18 tons of animal manure and a crop of cowpeas turned under had an average organic content during the 6-year period of .74 per cent; at the end of 6 years, the amount of organic material in the soil on this plot was .91 per cent, an increase of 146 per cent. The increase in the average organic content of the best treatments and the check plot over the 6-year period, was nine times that required for significance or seven times that required for high significance. These differences were, therefore, not chance differences.

The differences in the percentages of organic matter in soils receiving different treatments fall into distinct groups (Table I). The breaks between the groups are clear cut. In the table the breaks between groups differing by the amount required for significance at the .05 level are indicated by italics. These breaks correspond in a remarkable way to treatments. The major breaks in organic content correspond to applications of different rates of animal manure. The two groups having the lowest percentage of organic content received no animal manure. The third group in ascending order of organic content, received 6 tons per acre of animal manure, the fourth group 12 tons, the fifth group either 18 tons without a legume turned under, or 12 tons with a legume turned under, and the sixth group 18 tons of animal manure.

The average soil organic content over the period in the treatments receiving no animal manure ranged from .37 to .43 per cent; the range was from .52 to .54 per cent in the treatments receiving 6 tons of manure, from .59 to .66 per cent in the treatments receiving 12 tons of manure, and from .68 to .74 per cent in the treatments receiving 18 tons per acre of animal manure. The largest difference between any two treatments was .37 per cent.

The increases in the percentage of organic matter resulting from the turning under of a legume were small, but in most instances they were highly significant. The organic matter was increased .05 per cent[1] by turning under a legume crop where animal manure was not added (lines 14 and 11; 13 and 10); this increase was highly significant. The turning under of a legume crop increased the soil organic matter .06 per cent where 18 tons of manure was also added (lines 3 and 1). The increase for a turned under legume was .07 per cent where 12 tons of manure was added (lines 6 and 4) and .02 per cent where 6

[1]This refers to absolute and not relative increase.

tons of manure was added (lines 9 and 7). There were small b consistent differences in the percentage of soil organic matter in tre: ments receiving turned under nonlegumes and nonlegumes grown a removed. These differences were not significant, except in one instan(

The rate of application of fertilizer had no appreciable effect dire or indirect on the amount of soil organic matter.

## EFFECTS OF FERTILIZERS AND ORGANIC TREATMENTS ON SOIL NITRATES

Analyses of the soil for nitrates were made from samples tak( periodically at 2- to 3-week intervals in the fall and in the spring. R sults of the two periods are reported separately (Tables I and II The green manure crops were turned under in the late summer.

In interpreting the results obtained in the spring and fall, it shou be recognized that the nitrates released from turning under summ( legumes did not affect the nitrate content of soil during the growir of spring crops. This was due to its removal from the soil befoı spring by the fall crops and by leaching during the winter. Althougl the animal manure was applied in late winter, the nitrates in the so during the spring growing season, resulting from the application ( animal manure were unusually low because of leaching by heav rains during the late winter and early spring.

*Effects of Treatments on Nitrates in the Spring:*—The amount ( nitrates found in the soil during the spring was governed to a larg degree by the rate of application of commercial fertilizer, and to a les degree by the amount of animal manure applied and the type of gree manure turned under (Table I). While the rate of application of com mercial fertilizer was the most important factor in determining th soil nitrates in the spring, high amounts of nitrates were found onl in soils receiving a combination of high rates of fertilizers and manure: The three highest percentages of nitrates were found in soils fron plots receiving 2,000 pounds of commercial fertilizer and 18 tons o animal manure. The fourth, sixth, and seventh highest nitrate per centages were found in soils receiving 1,500 pounds of fertilizer an( 12 tons of manure; the fifth and eighth highest percentages of nitrate however, were found in soils receiving 2,000 pounds of commercia fertilizer, but no animal manures. The fact that the soil having th( fifth highest percentage of soil nitrates and the eighth highest per centage both of which received 2,000 pounds of commercial fertilizeı but neither of which received animal manure, is evidence that th( rate of fertilizer was exerting a greater influence on the supply of soi nitrates in the spring than animal manure.

By comparison of treatments, differing by a single variable, i would appear that for the spring period where no organic materia has been added an average increase in soil nitrates of 16.6 ppm[2] wa: attributable to a 1,500-pound application of fertilizer (lines 16 and 14), and 9.4 ppm attributable to a 1,000-pound application of fertilizeı

[2]Soil nitrates are expressed as $NO_3$.

TABLE I—SOIL ORGANIC MATTER, SOIL NITRATES, SOIL MOISTURE, AND CROP YIELDS IN PLOTS RECEIVING DIFFERENT SOIL TREATMENTS (SPRING)

| | Treatment | | | | Base Order** | Organic Matter | | Nitrates | | Soil Moisture‡ | | Order and Amount of Yield Per Acre of Crops 4-Year Average | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Potatoes | | Cabbage | | Lettuce | | Beans | |
| | Fertilizer 6–10–6 (Pounds) | Manure (Tons) | Legume* | Nonlegume* | | Order† | Amount (Per Cent) | Order† | Amount (Ppm) | Order† | Amount (Per Cent) | Order† | Yield (Bushels) | Order† | Yield (Pounds) | Order† | Yield (Pounds) | Order† | Yield (Bushels) |
| Column 1 Line | 2 | 3 | 4 | 5 | 6 | | 7 | | 8 | | 10 | | | | | | | | |
| 1..... | 2,000 | 18 | T | O | 1 | 1 | 0.74 | 2 | 30.4 | 3 | 9.19 | 2 | 157 | 5 | 23,987 | 2 | 22,182 | 1 | 140 |
| 2..... | 2,000 | 18 | O | T | 2 | 2 | *0.73* | 1 | 31.1 | 1 | 9.59 | 3 | 152 | 2 | 26,010 | 1 | 22,746 | 3 | 135 |
| 3..... | 2,000 | 18 | O | R | 3 | 3 | 0.68 | 3 | 29.3 | 2 | 9.48 | 1 | 180 | 1 | 27,059 | 3 | 22,157 | 2 | 136 |
| 4..... | 1,500 | 12 | T | O | 4 | 4 | *0.66* | 6 | 22.3 | 5 | 8.26 | 6 | 127 | 3 | 25,267 | 4 | 25,531 | 6 | 120 |
| 5..... | 1,500 | 12 | O | T | 5 | 5 | 0.62 | 4 | 26.1 | 4 | 8.58 | 4 | 138 | 4 | 25,165 | 5 | 19,930 | 5 | 126 |
| 6..... | 1,500 | 12 | O | R | 6 | 6 | *0.59* | 7 | 21.2 | 6 | 7.96 | 5 | 134 | 9 | 19,584 | 6 | 17,498 | 4 | 129 |
| 7..... | 1,000 | 6 | T | O | 7 | 7 | 0.54 | 11 | 16.6 | 7 | 7.55 | 7 | 112 | 10 | 16,845 | 8 | 14,323 | 8 | 97 |
| 8..... | 1,000 | 6 | O | T | 8 | 8 | 0.54 | 10 | 16.7 | 8 | 7.55 | 8 | 102 | 11 | 16,154 | 7 | 14,694 | 7 | 100 |
| 9..... | 1,000 | 6 | O | R | 9 | 9 | *0.52* | 13 | 13.8 | 9 | 7.36 | 9 | 91 | 8 | 19,622 | 9 | 13,709 | 9 | 87 |
| 10..... | 2,000 | 0 | T | O | 10 | 11 | 0.42 | 5 | 22.9 | 12 | 6.79 | 11 | 84 | 6 | 20,186 | 10 | 8,563 | 11 | 70 |
| 11..... | 1,500 | 0 | T | O | 11 | 10 | 0.43 | 9 | 18.1 | 11 | 6.84 | 13 | 82 | 7 | 19,776 | 11 | 8,525 | 13 | 67 |
| 12..... | 1,000 | 0 | T | O | 12 | 12 | *0.41* | 15 | 12.4 | 10 | 6.85 | 14 | 72 | 12 | 14,707 | 14 | 6,170 | 14 | 50 |
| 13..... | 2,000 | 0 | O | R | 13 | 15 | 0.37 | 8 | 19.9 | 14 | 6.65 | 12 | 83 | 14 | 14,323 | 13 | 8,115 | 10 | 70 |
| 14..... | 1,500 | 0 | O | R | 14 | 13 | 0.38 | 12 | 16.6 | 16 | 6.55 | 10 | 89 | 13 | 14,541 | 12 | 8,192 | 12 | 68 |
| 15..... | 1,000 | 0 | O | R | 15 | 14 | 0.38 | 14 | 12.7 | 13 | 6.69 | 15 | 66 | 15 | 11,290 | 15 | 5,299 | 15 | 43 |
| 16..... | 0 | 0 | O | R | 16 | 16 | 0.37 | 16 | 3.3 | 15 | 6.58 | 16 | 34 | 16 | 2,662 | 16 | 422 | 16 | — |
| Least significant Difference at | | | | 0.05 level | | | 0.04 | | 2.96 | | 0.42 | | 19 | | 3,034 | | 2,419 | | 84 |
| | | | | 0.01 level | | | 0.05 | | 3.96 | | 0.56 | | 26 | | 4,070 | | 3,238 | | 113 |

*In treatments marked T, green manures were turned and in those marked R removed.
**Base order refers to arrangements of treatments from high to low according to their effects on soil organic content, soil nitrates, and crop yields.
†Relative order from high to low of measured effects for each given treatment.
‡Average of samples taken at three periods from four plots each of three years, 1945, 1946, and 1947.

TABLE II—SOIL ORGANIC MATTER, SOIL NITRATES, SOIL MOISTURE, AND CROP YIELDS IN PLOTS RECEIVING DIFFERENT SOIL TREATMENTS (FALL)

| | Treatment | | | | Base Order** | Organic Matter | | Nitrates | | Soil Moisture‡ | | Order and Amount of Yield Per Acre of Crops 4-Year Average: Mustard | | Turnips | | Chinese Cabbage | | Onion | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fertilizer 6-10-6 (Pounds) | Manure (Tons) | Legume* | Nonlegume* | | Order† | Amount (Per Cent) | Order† | Amount (Ppm) | Order† | Amount (Per Cent) | Order† | Yield (Pounds) | Order† | Yield (Pounds) | Order† | Yield (Pounds) | Order† | Yield (Pounds) |
| Column 1 Line | 2 | 3 | 4 | 5 | 6 | | 7 | | 9 | | 10 | | | | | | | | |
| 1..... | 2,000 | 18 | T | O | 1 | 1 | 0.74 | 1 | 120 | 3 | 7.08 | 6 | 17,638 | 3 | 41,395 | 2 | 53,389 | 1 | 13,120 |
| 2..... | 2,000 | 18 | O | T | 2 | 2 | 0.73 | 2 | 101 | 2 | 7.20 | 1 | 19,430 | 6 | 38,387 | 4 | 50,010 | 5 | 10,445 |
| 3 .... | 2,000 | 18 | O | R | 3 | 3 | 0.68 | 3 | 94 | 1 | 7.32 | 5 | 18,086 | 4 | 39,437 | 1 | 54,643 | 4 | 10,534 |
| 4..... | 1,500 | 12 | T | O | 4 | 4 | 0.66 | 4 | 85 | 5 | 6.44 | 3 | 18,355 | 1 | 41,536 | 3 | 51,034 | 2 | 12,672 |
| 5..... | 1,500 | 12 | O | T | 5 | 5 | 0.62 | 5 | 68 | 6 | 6.35 | 2 | 19,392 | 2 | 41,510 | 6 | 45,030 | 3 | 11,110 |
| 6 .... | 1,500 | 12 | O | R | 6 | 6 | 0.59 | 6 | 65 | 4 | 6.63 | 4 | 18,317 | 7 | 37,747 | 7 | 44,890 | 7 | 9,088 |
| 7..... | 1,000 | 6 | T | O | 7 | 7 | 0.54 | 7 | 65 | 8 | 6.18 | 7 | 17,165 | 5 | 39,270 | 5 | 47,846 | 6 | 10,317 |
| 8..... | 1,000 | 6 | O | T | 8 | 8 | 0.54 | 10 | 48 | 7 | 6.19 | 8 | 14,797 | 8 | 30,899 | 8 | 34,163 | 8 | 8,230 |
| 9..... | 1,000 | 6 | O | R | 9 | 9 | 0.52 | 12 | 41 | 9 | 5.94 | 9 | 13,274 | 9 | 30,515 | 11 | 28,557 | 10 | 7,053 |
| 10..... | 2,000 | 0 | T | O | 10 | 11 | 0.42 | 8 | 60 | 13 | 5.77 | 10 | 11,776 | 11 | 29,222 | 10 | 29,248 | 11 | 7,283 |
| 11..... | 1,500 | 0 | T | O | 11 | 10 | 0.43 | 9 | 54 | 16 | 5.67 | 11 | 11,187 | 10 | 30,374 | 9 | 29,427 | 9 | 8,128 |
| 12..... | 1,000 | 0 | T | O | 12 | 12 | 0.41 | 13 | 39 | 11 | 5.81 | 12 | 9,792 | 12 | 28,160 | 12 | 27,302 | 13 | 5,734 |
| 13..... | 2,000 | 0 | O | R | 13 | 15 | 0.37 | 11 | 44 | 15 | 5.72 | 13 | 7,078 | 14 | 18,829 | 13 | 16,077 | 12 | 5,491 |
| 14 .... | 1,500 | 0 | O | R | 14 | 13 | 0.38 | 14 | 38 | 10 | 5.87 | 14 | 6,592 | 13 | 20,198 | 14 | 12,826 | 14 | 4,710 |
| 15..... | 1,000 | 0 | O | R | 15 | 14 | 0.38 | 15 | 28 | 12 | 5.79 | 15 | 5,261 | 15 | 15,667 | 15 | 10,138 | 15 | 3,469 |
| 16..... | 0 | 0 | O | R | 16 | 16 | 0.37 | 16 | 6 | 14 | 5.74 | 16 | — | 16 | 794 | 16 | — | 16 | — |
| Least significant | | | 0.05 level | | | 0.04 | | | 7.61 | | 0.46 | | 2,496 | | 4,800 | | 7,104 | | 1,997 |
| Difference at | | | 0.01 level | | | 0.05 | | | 10.81 | | 0.62 | | 3,430 | | 6,336 | | 9,510 | | 2,790 |

*In treatments marked T, green manures were turned and in those marked R removed.
**Base order refers to arrangements of treatments from high to low according to their effects on soil organic content, soil nitrates, and crop yields.
†Relative order from high to low of measured effects for each given treatment.
‡Average of samples taken at three periods from four plots each of three years, 1945, 1946, and 1947.

(lines 15 and 16). Continuing the comparison, it would seem that an average increase in soil nitrates of 9.4 ppm was attributable to the addition of 18 tons of manure (lines 13 and 3), 4.6 ppm attributable to 12 tons of manure (lines 14 and 6), and 1.1 ppm to 6 tons of animal manure (lines 15 and 9) where no other organic treatment was involved. The increase in nitrates resulting from an increase in the rates of fertilizer application from 1,000 to 1,500 pounds per acre was only 3.9 ppm; the increase in nitrates resulting from an increase in fertilizer application from 1,500 pounds to 2,000 pounds was only 3.3 ppm (lines 13, 14, and 15).

Differences in soil nitrates in the spring due to the turning under of a legume or a nonlegume crop, or to application of 6 tons of animal manure were below or barely at the required .05 level for significance. A difference of 2.96 ppm was required for significance at the .05 level.

It is significant to note that only with high applications of fertilizers and manures were even moderate amounts of soil nitrates obtained in the spring.

*Effects of Treatments on Nitrates in the Fall:*—Relative effects of the different soil treatments on soil nitrates were different in the fall and in the spring. Legumes having been recently turned under played a more important role in determining the amount of nitrates in the soil during the fall period than during the spring period. Of the several treatments used, commercial fertilizers exerted the greatest influence on soil nitrates in the fall. This was also the case in the spring.

It should be noted that the order of sequence in the amount of soil nitrates found in the fall correspond very closely to the base order of treatments (Table II). Where the actual order of the nitrate percentages departed from the base order of treatments, it was generally due to legume treatments giving higher soil nitrates than the higher base order treatments without the legume turned under.

By comparison of treatments differing by a single variable, as was done in previous comparisons, an average increase in soil nitrates in the fall over a 7-year[3] period of about 10 to 26 ppm was apparently due to turning under legumes. Six comparisons are possible to measure the value of legumes in increasing soil nitrates. Legumes increased the nitrate content of the soil more when used in combination with animal manures than when not used with animal manures. Likewise, the increases in soil nitrate attributable to manures were higher in plots receiving legumes than in plots not receiving legumes.

In the fall, a legume crop turned under increased the nitrate content of the soil in plots receiving 2,000 pounds of a commercial fertilizer with no manure 16 ppm (lines 10 and 13). The increase in soil nitrates from turning under a legume in plots receiving 2,000 pounds per acre of a commercial fertilizer and 18 tons of manure was 26 ppm (lines 1 and 3). The increase by similar comparison in the nitrate

[3]The data for soil nitrates represent 7-year averages; the data for soil organic 6-year averages.

content of the soil from turning under a legume in plots receiving 1,500 pounds of a commercial fertilizer was 16 ppm without an animal manure, 20 ppm with an animal manure (lines 11 and 14; 4 and 6), and those receiving 1,000 pounds of a commercial fertilizer 11 ppm without an animal manure and 24 ppm with an animal manure (lines 12 and 15, and 7 and 9).

By comparisons involving only one variable, 1,000 pounds per acre of a commercial fertilizer in the fall without the addition of any organic material increased the nitrate in the soil 22 ppm (lines 16 and 15); 1,500 pounds of fertilizer increased the nitrates 32 ppm (lines 16 and 14); and 2,000 pounds of fertilizer increased the nitrates 38 ppm (lines 16 and 13).

Continuing the comparison with only one variable, 6 tons of animal manure without legumes turned under increased the soil nitrates in the fall 13 ppm (lines 15 and 9), 12 tons of manure 27 ppm (lines 14 and 6), and 18 tons of manure 50 ppm (lines 13 and 3). Where legumes were turned under in addition to manure, 6 tons of animal manure increased the soil nitrates 26 ppm (lines 12 and 7), 12 tons of animal manure 31 ppm (lines 11 and 4), and 18 tons of animal manure 60 ppm (lines 10 and 1).

The greater increases in soil nitrates from the application of animal manures on plots where legumes were turned under than where not turned under and the greater increases from the turning under of the legume on plots receiving animal manure than on those not receiving animal manure were most probably due to the larger legume growth. This indicates that the percentage of soil nitrates were affected strongly by the interaction of legumes and animal manure.

The average nitrate content of the soil in the spring on plots receiving no treatment was only 3.7 ppm and in the fall only 6 ppm. The amounts of nitrate in the soil in the fall for corresponding treatments were two to four times as high as in the spring. The differences were partly due to the losses of nitrates during the winter from leaching rains, which reduced nitrates by spring, and partly to increases in nitrates resulting from turning under a summer legume immediately preceding the fall period.

## Effects of Fertilizer and Organic Treatments on Soil Moisture

The soil moisture percentages given in Tables I and II are based on the average of samples taken during the spring and the fall for a 3-year period, 1945–7. The treatments, therefore, had had opportunity to build up some differences if any were to develop.

*Effects of Treatments on Soil Moisture in the Spring:*—Animal manure applications affected the soil moisture much more than the other treatments. The three highest average moisture percentages in the spring were found in soils from plots receiving 18 tons of animal manure; the second three highest percentages were from plots receiving 12 tons of animal manure, and the third three highest percentages were from plots receiving 6 tons of manure.

In the spring there were highly significant differences found in the

moisture percentages in soils from plots receiving 18 tons and 12 tons of animal manure and between those receiving 12 tons or 6 tons and those receiving no manure.

Differences in moisture content between green manure treatments were not significant where an animal manure was not also added, and were significant in only one instance where animal manure was also added.

*Effects of Treatments on Soil Moisture in the Fall:*—In the fall the only significant differences in soil moisture were found in plots receiving different amounts of animal manures. The differences in soil moisture were significant or highly significant between plots receiving 18 and 12, 18 and 6, and 12 and 0 tons per acre of animal manure.

## Influence of the Several Soil Treatments on the Yield of Crops in the Spring

In Table I is given the actual yield of each crop for each treatment, as well as the number indicating the relative order of yield.

In general, rates of fertilizer application and rates of animal manure in the order named exerted the dominant influence on the yield of spring crops. Green manure played a minor role. It should be pointed out, however, that the high yields came from a combination of high applications of both fertilizer and manure. This follows the general pattern pointed out in regard to nitrate content as affected by soil treatments.

Considering all four spring crops, the first nine highest yields were found in the first nine treatments in the base order except in the case of cabbage. The first three highest yields came from treatments consisting of 2,000 pounds of fertilizer and 18 tons of manure, the second three highest yields came from treatments consisting of 1,500 pounds per acre of fertilizer and 12 tons per acre of manure, and the third three highest yields from treatments consisting of 1000 pounds per acre of fertilizer and 6 tons of manure.

There was no consistent sequence in the yield of the crops associated with or resulting from turning under a legume or nonlegume, or the growing and removal of a nonlegume. Considering the 48 possible comparisons, with other treatments comparable, there were only 12 instances of significant differences in yields between treatments where legumes were turned under, where nonlegumes were turned under, or where nonlegumes were grown and removed. In only 6 of the 36 possible comparisons between legumes and nonlegumes with other treatments comparable were there significant increases in yield of legume plots over nonlegume plots. It may be recalled that in only one instance were nitrates in the spring increased significantly by the turning of a legume the preceding summer. The agreements in the spring between soil nitrates, soil treatments, and yields were very close.

It should be pointed out that in many instances there were consistent increases in the yield of spring crops attributable to turning under a green manure crop but that the differences were not sufficient for significance at the .05 level. This was especially true in the case of lettuce.

## Influence of the Several Soil Treatments on the Yield of Crops in the Fall

Turning of a summer legume affected the yield of fall crops to a much greater degree than it did the yield of spring crops (Table II). It should be recalled that the turning under of a summer legume affected soil nitrates in the fall to a much greater degree than it did in the spring.

Examination of data for the fall crops reveals little consistency in the order of yields for crops receiving 1,500 pounds per acre of fertilizer and 12 tons of animal manure or higher rates of these two materials (lines 1, 2, 3, 4, 5, and 6). For instance, the first three highest yields were as likely to result from treatments of 1,500 pounds of fertilizer and 12 tons of animal manure as they were from 2,000 pounds of fertilizer and 18 tons of animal manure. Furthermore, the highest yield within each group was just as likely to be found in treatments receiving as not receiving a green manure crop. In each of these treatments, an average soil nitrate content of 65 ppm or above was found. Apparently, with nitrates at this level, the maximum capacity of the soil to produce crops without some form of irrigation had been reached and yields were, therefore, not affected by higher rates of fertilizer or manures or by turning under a legume.

Turning under legumes and also application of higher rates of fertilizer did affect yield and order of yields for treatments having an average soil nitrate content below 65 ppm.

The yield of each of the fall crops, with the exception of onions at one fertilizer rate, was significantly increased when legumes were turned under with treatments receiving either 1,000, 1,500, or 2,000 pounds per acre of fertilizer without animal manure (lines 15 and 12; 14 and 11; 13 and 10).

Although the yields of fall crops were greatly increased by turning under a legume crop, the addition of manures increased yields considerably more than the turning under of a legume. With all crops, at each of the three rates of fertilizer application, highly significant increases in yields were obtained from the addition of animal manure (lines 12 and 7; 11 and 4; 10 and 1).

Increases in yield of fall crops resulting from increases in the rates of application of fertilizer without organic treatments were small and were either below or barely significant at the .05 level (lines 15, 14, and 13).

With one exception, there were significant or highly significant increases in the yield of plots receiving 1,000 pounds per acre of fertilizer and 6 tons of animal manure over those receiving 1,500 pounds and 2,000 pounds of fertilizer but without organic material (lines 7, 8, and 9 compared to lines 13 and 14). There was also significant differences in the yields of crops receiving 1,000 pounds of fertilizer, 6 tons of animal manure and a legume, and those receiving 1,500 or 2,000 pounds of fertilizer and legume but receiving no animal manure (lines 7 compared to lines 10 and 11).

It should be noted that yields of plots receiving 1,000 pounds per

acre of fertilizer, 6 tons of manure and a turned legume (line 7) were practically as high as any treatment receiving higher rates of fertilizer and animal manure. This treatment had an average of 65 ppm. $NO_3$. It was pointed out earlier that with few exceptions, this was the amount above which differences between treatments were not significant but below which differences were significant.

On plots receiving 1,000 pounds per acre of a fertilizer and 6 tons of manure, there were highly significant difference in yield of each fall crop between treatments where legumes were turned under and no legume was turned. In the same series of plots there were significant differences in yields from turning under and not turning under. On the other hand there was no significant difference between yields where nonlegumes were turned under and nonlegumes were removed.

## Summary

This investigation includes a study of effects of applying different rates of fertilizer and animal manure and of growing different types of green manures on the organic, nitrate and moisture content of the soil and on the yields of truck crops. The study was conducted for a period of 7 years.

The treatments included nine combinations of fertilizer, animal manure, and green manure, six combinations of fertilizer and green manure, and one treatment with no fertilizer, no animal manure, and no green manure. The fertilizer rates were 0, 1,000, 1,500, and 2,000 pounds per acre to each of the spring and fall crops; the manure rates were 0, 6, 12, and 18 tons per acre applied in late winter; and the green manure treatments consisted of summer legumes turned under, summer nonlegumes turned under, and summer nonlegumes grown and removed.

The treatments in the tables are arranged, in general, according to their effects on soil organic content, soil nitrates, soil moisture, and crop yields ranging from high to low. This arrangement is referred to as the base order of treatments.

The relative order from high to low as well as the actual quantities of each effect measured is indicated in the tables for each of the treatments given.

The patterns of the order of treatments and of the order of the relative amounts of organic matter, nitrates, and moisture found in soil and of crop yields obtained were remarkably similar. The similiarity of patterns tend to show a close relationship between the treatments given, the effects of these treatments on soil factors, and the effects of soil factors on crop yields.

The effects of soil treatments on soil factors and on crop yields differed in the spring and in the fall. In the spring, in general, the rates of application of fertilizer had the greatest affect and the rates of application of animal manure had the second greatest affect on the amount of nitrates in the soil and on the yields of crops. Green manures did not affect the nitrates or the yield in the spring significantly.

Highest crop yields, soil nitrates, soil organic content, and soil moisture resulted from high applications of commercial fertilizer and

animal manure. Soil moisture, in general, was not affected significantly by treatments other than by applications of animal manure.

In the fall green manures affected soil nitrates and crop yields much more than in the spring. The amount of nitrates in the soil corresponded closely with the base order of treatments. Where the actual order of ppm $NO_3$ departed from the base order of treatments, it was generally due to the higher nitrates found in soils receiving turned legumes without animal manure than found in treatments receiving 6 tons per acre of animal manure without a legume turned under.

Nitrates were so high in the soil in the fall that there was little consistency in the order of crop yields for any treatment receiving as much as 1,500 pounds of commercial fertilizer and 12 tons of manure. It appeared that soil nitrates averaging 65 ppm provided maximum amounts for crop yields. Amounts in excess of 65 ppm $NO_3$ did not result in higher crop yields.

The organic content of the soil on which the studies were made was very low. After 6 years of repeated applications of manures, the organic content of the soil was still low, although some treatments had resulted in increases as high as two and one-half times the original amount found in the soil at the beginning of the experiment.

Commercial fertilizers did not affect directly or indirectly the amount of organic matter in the soil. Increases in percentage of organic matter in the soil attributable to legumes turned under were small but statistically significant.

Animal manure affected the percentage of soil organic matter considerably more than other treatments; each increase in the rate of application of animal manure resulted in a significant increase in the percentage soil organic matter.

Animal manure increased significantly the average moisture content of the soil. The differences were significant between treatments receiving 18 tons per acre and those receiving 12 or 6 tons and significant between those receiving 12 tons or 6 tons and those receiving no manure.

## Literature Cited

1. Jenny, Hans. Relation of climatic factors to the amount of nitrogen in soils. *Jour. Amer. Soc. Agron.* 20: 900–912. 1928.
2. ———— Study on the influence of climate upon the nitrogen and organic matter content of the soil. *Mo. Agr. Exp. Sta. Res. Bul.* 152. 1930.
3. Albrecht, W. A. Loss of soil organic matter and its restoration. *U. S. D. A. Yearbook* 347–360. 1938.
4. Ware, L. M., and Johnson, W. A. Effects of fertilizers, animal manures and green manures on the yield of vegetable crops on light garden soils. *Proc. Amer. Soc. Hort Sci.* 46: 319–322. 1945.

# Field Studies on the Mineral Nutrition of the Sweetpotato[1]

By O. A. LEONARD, W. S. ANDERSON and MARVIN GIEGER[2],
*Mississippi Agricultural Experiment Station,*
*State College, Miss.*

SOILS differ greatly in the manner in which they supply different nutrients to plants. Nutrients are frequently present in the soil in quantities insufficient for maximum yield. Soil analyses can give valuable information regarding the relative abundance of nutrients; however, since the plants integrate the total of all environmental factors while growing, the plants themselves should give useful information regarding the nutrient status of the plant in terms of potential yield. For these reasons the investigations reported herein were begun to study the relation of mineral composition of the leaf blades of sweet potatoes to yield of the fleshy roots.

## MATERIALS AND METHODS

Sprouts of Unit 1 Porto Rico were set in Ruston sandy loam at the South Mississippi Branch Station at Poplarville on April 30, 1946, and on May 6, 1947. In both years, various fertilizer materials, sodium nitrate, triple-superphosphate, potassium chloride, calcium carbonate, and magnesium sulphate were varied independently of each other. The sodium nitrate, triple-superphosphate, potassium chloride, and calcium carbonate, were each applied to supply 0, 80, and 160 pounds of N, $P_2O_5$, $K_2O$, and CaO per acre respectively and the magnesium sulphate was applied to supply 0, 50, and 100 pounds per acre of magnesium oxide. When one salt was varied the others were held at a constant level of 80 pounds per acre, with the exception of magnesium sulphate which was held at the rate of 50 pounds of MgO per acre. The experimental area was treated with 15 pounds of borax in 1946 and 5 pounds in 1947. The plots were arranged in six randomized complete blocks and a single block consisted of a single row 60 feet long in 1946 and of three adjacent rows 24 feet long in 1947. Leaf blades of the first five fully enlarged leaves from tips of the vines were collected for mineral analyses, and vine and root weights were recorded on July 11, August 5, August 28, September 20, and October 16 in 1946 and on October 20 in 1947. The leaf blades and fleshy roots were analyzed in the laboratory of the Chemistry Department at State College.

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[2]Plant Physiologist; Head, Department of Horticulture; and Chemist, respectively.

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## Discussion

*Results in 1946:*—The results on the effects of sodium nitrate on the composition of the leaf blades and total yield of the roots are presented graphically in Fig. 1. In general they show that the applications of sodium nitrate markedly influenced the percentage of nitrogen, slightly influenced the percentage of potassium, and had little effect on the percentage of phosphorus, calcium, and magnesium. For any given stage of growth, the plants which received 160 pounds of nitrogen per acre had a significantly greater nitrogen content than those which received 80 pounds per acre, and these in turn had a significantly greater nitrogen content than the plants which received the zero application.

Further, the data show that, regardless of the available nitrogen supply, the nitrogen content of the leaf blades gradually declined as the plants approached maturity. Nevertheless, the leaf blades of the plants which received the 160 pound-per-acre application always had the highest nitrogen content, those which received the zero application always had the lowest nitrogen content, and those which received the 80 pound-per-acre application always had intermediate amounts. Evidently the amount of available nitrogen present markedly influences the nitrogen content of the leaf blades of the Unit I Porto Rico sweetpotato.

The applications of sodium nitrate also influenced the total yield of roots. The plants which received 80 pounds of nitrogen per acre produced significantly higher yields than those which received the zero application, and those which received 160 pounds of nitrogen per acre produced, on the average, slightly higher yields than those which received the 80 pound-per-acre application. Since the nitrogen content of the leaf blades and total yields varied directly, and more or less closely, with the available nitrogen supply, the question arises, can the nitrogen content of the leaf blades be used as an index to the nitrogen requirements of the sweetpotato crop? These results, though preliminary, indicate that the leaf blade should contain at least 3.5 per cent nitrogen about 170 days after planting to secure satisfactory yields. Further experiments are necessary before definite recommendations can be made.

The results on the effect of potassium chloride are shown graphically in Fig. 2. In general, they show that the application of potassium chloride had no influence on the nitrogen content of the leaf blades, influenced the potassium and calcium content, and had no influence on the magnesium and phosphorus content. The plants which received the 80 pounds and 160 pounds of potash respectively had a consistently higher potassium content than those which received the zero application. Although the effects of applications of potassium chloride on the potassium content of the leaf blade were not as striking as that of applications of sodium nitrate on the nitrogen content, the results indicate that increases in supplies of potassium chloride increased the potassium content.

As with the sodium nitrate series, the applications of potassium chloride influenced the total yield of roots. The plants which received 80 pounds of potash per acre produced significantly higher yields than

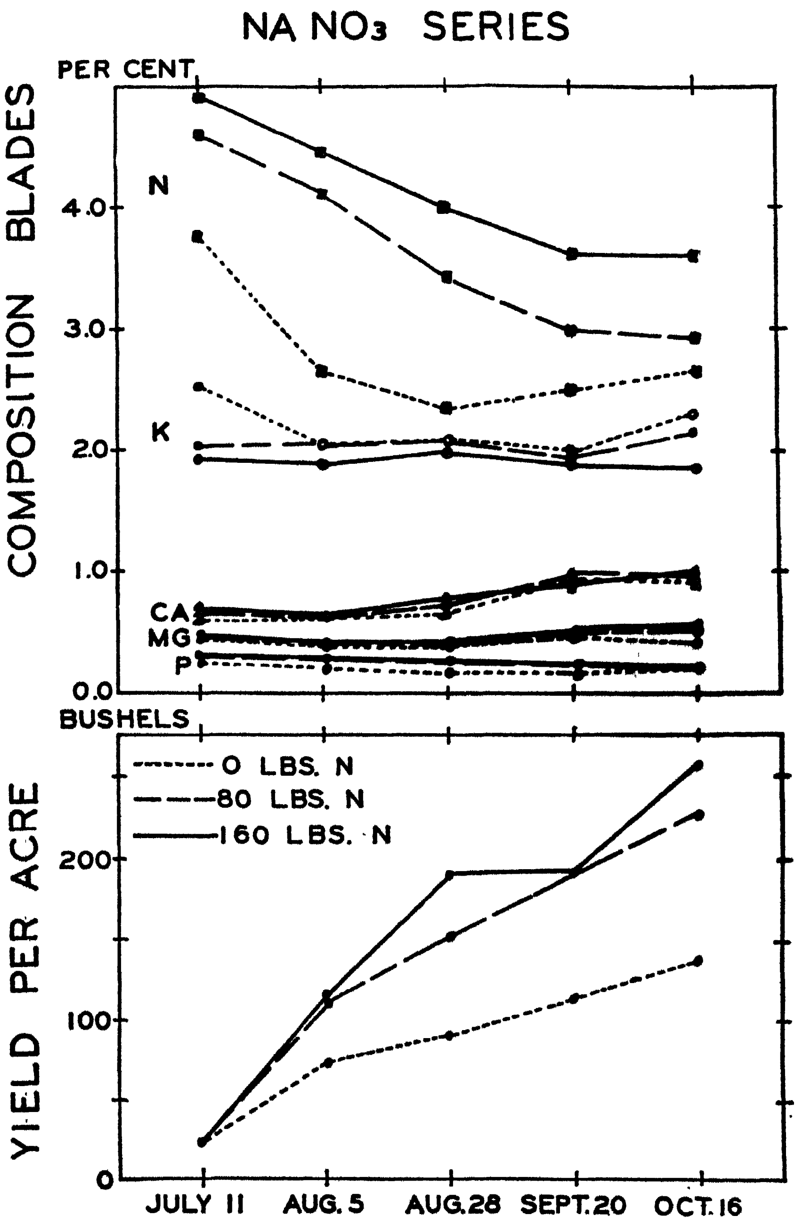


FIG. 1. Sodium nitrate series. Seasonal changes in the chemical composition of the leaf blades and total yield of the storage roots of Unit 1 Porto Rico sweetpotatoes on Ruston sandy loam. Popularville, Mississippi, 1946.

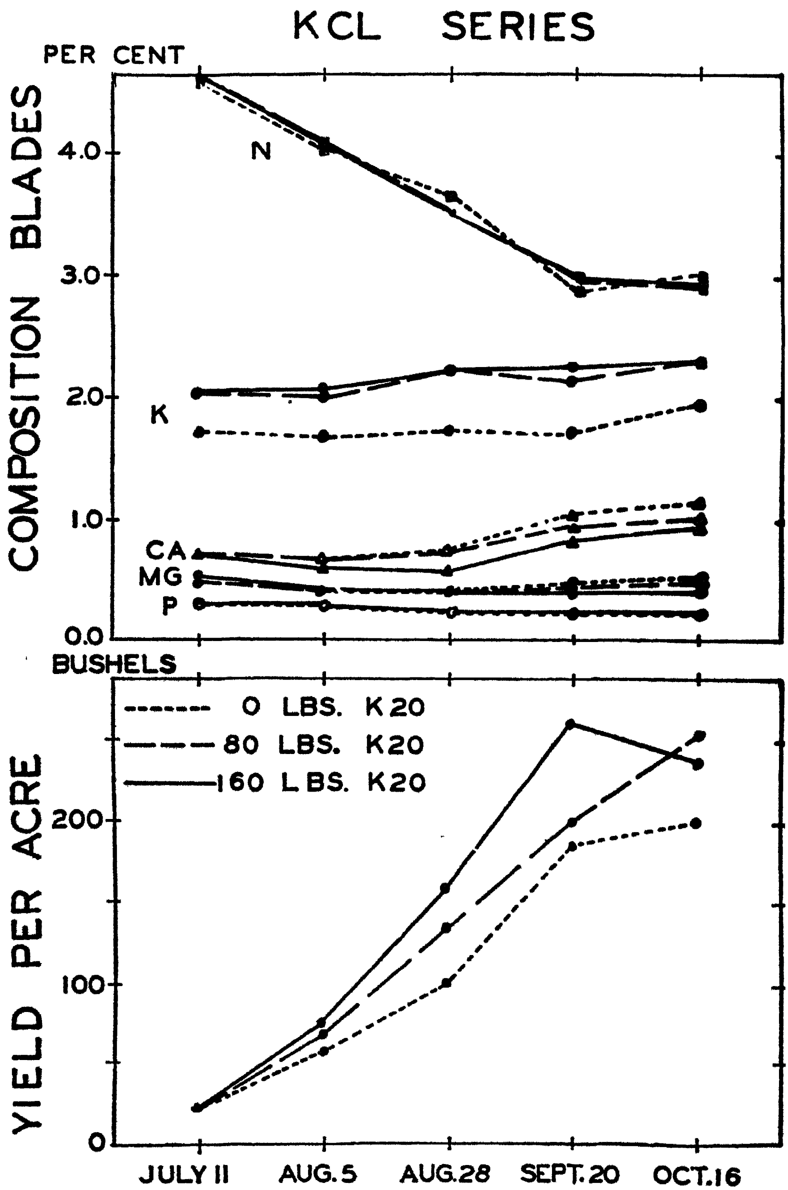


FIG. 2. Potassium chloride series. Seasonal changes in the chemical composition of the leaf blades and total yield of the storage roots of Porto Rico sweetpotatoes on Ruston sandy loam. Popularville, Mississippi, 1946.

those which received the zero application, and those which received the 160 pound-per-acre application produced higher yields than those which received the 80 pound-per-acre application. As with nitrogen, the question arises, can the percentage of potassium of the leaf blades be used as a reliable index to the potassium requirements of the crop? In these tests the highest yields were associated with at least 2 per cent of potassium in the leaf blades. However, further tests are necessary before definite recommendations can be made.

*Results in 1947:*—The data presented in Table I show a wider variation in yields in the sodium nitrate, superphosphate, and potassium chloride series than in the calcium carbonate and magnesium sulphate series. With the nitrogen, phosphorus, and potassium series,

TABLE I—THE EFFECT OF FERTILIZATION ON THE YIELD OF PORTO RICO SWEETPOTATO ROOTS AND CHEMICAL COMPOSITION OF THE LEAF-BLADES (1947)

| Treatment | | Yield of Roots Per Acre (Bu) | | Chemical Composition of Leaf-Blades at Harvest—Dry Bases (Per Cent) | | | | |
|---|---|---|---|---|---|---|---|---|
| Chemical | Rate (Lbs) Per Acre | Marketable | Total | N | P | K | Ca | Mg |
| N | 0 | 78 | 141 | 2.48 | 0.28 | 2.25 | 0.99 | 0.46 |
| N | 80 | 156 | 226 | 3.12 | 0.23 | 2.06 | 1.00 | 0.49 |
| N | 160 | 165 | 262 | 3.83 | 0.24 | 2.02 | 1.02 | 0.53 |
| $P_2O_5$ | 0 | 134 | 201 | 3.13 | 0.20 | 2.05 | 1.01 | 0.51 |
| $P_2O_5$ | 80 | 168 | 230 | 3.26 | 0.23 | 2.11 | 0.97 | 0.47 |
| $P_2O_5$ | 160 | 214 | 290 | 2.92 | 0.23 | 2.15 | 1.10 | 0.49 |
| $K_2O$ | 0 | 106 | 166 | 3.31 | 0.22 | 1.61 | 1.14 | 0.52 |
| $K_2O$ | 80 | 193 | 266 | 3.20 | 0.22 | 1.95 | 1.18 | 0.55 |
| $K_2O$ | 160 | 182 | 272 | 3.20 | 0.21 | 2.37 | 1.01 | 0.48 |
| CaO | 0 | 157 | 219 | 3.12 | 0.21 | 1.97 | 0.98 | 0.45 |
| CaO | 80 | 155 | 217 | 2.95 | 0.22 | 2.03 | 1.05 | 0.49 |
| CaO | 160 | 147 | 219 | 3.17 | 0.19 | 1.90 | 1.10 | 0.51 |
| MgO | 0 | 149 | 213 | 3.13 | 0.21 | 2.00 | 1.06 | 0.52 |
| MgO | 50 | 172 | 249 | 2.95 | 0.20 | 1.95 | 1.13 | 0.50 |
| MgO | 100 | 157 | 240 | 3.02 | 0.21 | 2.09 | 1.11 | 0.54 |

Differences between yields required for significance at 5 per cent:
N treatments, 26 bushels for total, 18 bushels for marketable
P treatments, 41 bushels for total, 24 bushels for marketable
K treatments, 23 bushels for total, 22 bushels for marketable
Differences not significant between means of:
1. Marketable and total for Ca treatments
2. Marketable and total for Mg treatments

there are significant differences in some cases and insignificant differences in others, and in the calcium and magnesium series there are no significant differences. In the yield of the marketable grade, the 80 pound-per-acre application of nitrogen, phosphorus, and potassium, respectively, produced significantly higher yields than the zero application of each nutrient, and the 160 pound application of phosphorus produced significantly higher yields than the 80 pound-per-acre application. In the total yield, the 160 pound-per-acre application of nitrogen produced significantly higher yields than the 80 pound-per-acre application, and this in turn produced significantly higher yields than the zero application; the 160 pound-per-acre application of phosphorus produced significantly higher yields than the 80 pound-per-acre application; and the 80 pound-per-acre application of the

potassium carrier produced significantly higher yields than the zero application. These results are similar to those obtained in 1946 and indicate that under the conditions of the experiment 80 pounds of nitrogen, from 80 to 160 pounds of phosphorus, and 80 pounds of potash are necessary for maximum yield.

## Conclusions and Summary

1. Plants of Unit 1 Porto Rico were grown in Ruston sandy loam and were supplied with zero, moderately high, and high quantities of available nitrogen, phosphorus, potassium, calcium, and magnesium to determine the relation of the mineral content of the leaf blades to the yield of the fleshy roots.
2. The applications of available nitrogen and of available potassium were definitely associated with the nitrogen and potassium content of the leaf blade and with the yields of the roots.
3. Plants with leaf blades varying from 4.7 to 5.0 per cent nitrogen in early summer and from 3.0 to 3.8 per cent at the harvest and with at least 2.0 per cent potassium during all stages of growth produced higher yields than those supplied with lesser quantities of available nitrogen and potassium.

# Interrelation of Spacing, Variety and Interplanting on Yield and Fruit Size of Tomatoes[1]

By M. L. Odland, *Pennsylvania Agricultural Experiment Station, State College, Penn.*

THE purpose of this study was to determine the most suitable planting distance for the determinate and the indeterminate type of tomatoes and to ascertain the influence of interplanting varieties (or types) on yield.

In Minnesota, Currence (1) found that decreasing the row spacing to as close as 1 by 4 feet increased yields of the varieties Dwarf Champion, Break O'Day and Pritchard. This increase in yield was accompanied by a very slight decrease in fruit size. Similar results were obtained by Larson and Currence (3) in Minnesota in a study of $F_1$ hybrid tomatoes. In Erie, Pennsylvania however, Larson (2) found that in some seasons the wider and the closer spacings gave equally great yields. Parker (4) in Virginia obtained favorable results from interplanting varieties.

## Materials and Methods

Four spacing distances in the row, 2 feet, 3 feet, 4 feet, and 6 feet, were considered. The distance between the rows (4 feet) was held constant to facilitate cultivation and to eliminate the allotment of excessive space to guard rows. Thus the spacing treatments were 4 feet by 2 feet, 4 feet by 3 feet, 4 feet by 4 feet, and 4 feet by 6 feet.

The varieties Pennheart and Rutgers were selected for the experiment. The former variety is determinate in vine growth habit and the ultimate size of the plant is small. It matures rapidly and produces a fair crop in a relatively short time. In late season the vines become woody and weak and production is generally insignificant. The latter variety is indeterminate in vine growth habit and the ultimate size of the plant is large. It is a late maturing variety which produces a good crop in regions where the growing season is fairly long. Thus these two varieties represent two distinct types in regard to vine growth and maturity. In addition to planting two varieties in plots alone, they were interplanted together in a plot.

The field layout was a split plot design. The main plots consisted of the spacing treatments. These were 48 feet wide, including guard rows, and 32 feet long, including guard plants; excluding the guard plants the length was 24 feet. Twenty-four feet proved to be a convenient length of plot since it would allow for exactly 4, 6, 8, and 12 plants per row to represent the 6 feet, 4 feet, 3 feet, and 2 feet spacing. The main or spacing plots were divided at random into three sub-plots to include the two varieties (types) and the interplanting. These three treatments will be referred to as the variety treatments. Each of these sub-plots was comprised of four rows 24 feet long; only the two center rows were harvested for record, how-

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ever, since the outer rows were guard rows between variety treatments. In the interplanted plot (at all four spacings) there was an equal number of the two varieties, Pennheart and Rutgers, planted alternately in the row. It should be noted that the sub-plots (variety plots) including the interplants, were entirely surrounded by guard rows or plants suitable with respect to plant type and to spacing. The entire experiment was replicated four times and conducted for two years, 1945 and 1946.

Well grown potted plants of both varieties were set in the field as soon as weather permitted which in both seasons was about May 25. The Pennheart plants, which were in blossom, were older and more mature than the Rutgers plants at field planting time, since they had been started earlier in the greenhouse.

The data obtained were subjected to the analysis of variance method of analysis. Since the sub-plots were Rutgers, Pennheart and Interplanted, comparisons among these could be made readily. However, in order to make comparisons between Rutgers in the interplanted plot with this variety grown alone, a separate analysis was made. Likewise a separate analysis was made in order to compare Pennheart in the interplanted plot with Pennheart grown alone. Obviously, for these comparisons the yield data from the interplanted plots had to be multiplied by two. The data for the two varieties grown in the interplanted plots, but considered independently, are given at the bottom of each table presented as experimental data.

Pickings were made as required, which as a rule was twice a week. For the purpose of analysis the results obtained from pickings up to August 22 are referred to as early harvest and the pickings made after this date are referred to as the late harvest.

## Experimental Results

### FRUIT SIZE

The total number of marketable fruits harvested from each plot for each year was recorded. From these data and the weight records the average weight or size of fruit for each plot was calculated for both the early and late harvests.

*1945:*—The fruit size data for both early and late harvest for 1945 are presented in Table I. The mean fruit size of the early harvest for the spacings 4 feet by 2 feet, 4 feet by 3 feet, 4 feet by 4 feet, and 4 feet by 6 feet were 5.87 ounces, 5.71 ounces, 5.71 ounces, and 5.81 ounces respectively. The differences among these means are very small and statistically not significant, nor is the difference between the mean fruit size of Pennheart and the mean fruit size of Rutgers significant. The results obtained from Pennheart interplanted are practically identical with those obtained from this variety when planted alone. Likewise Rutgers, when interplanted, behaved as Rutgers did when planted alone. It may be further noted that when the fruit size of Pennheart when grown alone and Rutgers when grown alone are averaged (line 7 in Table I) the results are very similar to the results obtained from the interplanted plot.

TABLE I—THE EFFECT OF PLANT SPACING ON THE WEIGHT IN OUNCES (SIZE) OF EARLY AND LATE HARVEST MARKETABLE FRUIT OF PENNHEART AND RUTGERS IN 1945 AND 1946.

| Variety | Early Harvest | | | | | Late Harvest | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means* | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means** |
| *1945* | | | | | | | | | | |
| Pennheart | 5.76 | 5.76 | 5.44 | 5.92 | 5.73 | 4.96 | 5.28 | 4.80 | 5.12 | 5.04 |
| Rutgers | 6.08 | 5.44 | 5.92 | 5.92 | 5.84 | 4.96 | 5.12 | 5.12 | 5.44 | 4.17 |
| Interplanted | 5.76 | 5.92 | 5.76 | 5.60 | 5.76 | 5.12 | 4.96 | 5.12 | 4.96 | 5.04 |
| Means of spacing† | 5.87 | 5.71 | 5.71 | 5.81 | — | 5.01 | 5.12 | 5.01 | 5.17 | — |
| Pennheart (interplanted) | 5.60 | 5 92 | 5.60 | 5.76 | 5.12 | 5.12 | 4.80 | 4.96 | 4.96 | 4.96 |
| Rutgers (interplanted) | 6.24 | 5.92 | 5.76 | 5.76 | 5.92 | 5.12 | 5.12 | 5.12 | 4.96 | 5.09 |
| Average of Pennheart and Rutgers | 5.92 | 5.60 | 5.68 | 5.92 | 5.78 | 4.96 | 5.21 | 4.96 | 5.28 | 5.10 |
| *1946* | | | | | | | | | | |
| Pennheart | 4.96 | 5.12 | 4.96 | 5.12 | 5.04 | 4.48 | 4.48 | 4.48 | 4.80 | 4.56 |
| Rutgers | 5.60 | 5.92 | 5.60 | 5.60 | 5.68 | 4.48 | 5.12 | 5.44 | 5.12 | 5.04 |
| Interplanted | 5.12 | 5.60 | 5.28 | 5.28 | 5.33 | 4.80 | 4.96 | 5.12 | 5.28 | 5.04 |
| Means of spacings‡ | 5.28 | 5.55 | 5.28 | 5.33 | — | 4.59 | 4.85 | 5.01 | 5.07 | — |
| Pennheart (interplanted) | 5.28 | 4.96 | 4.80 | 5.44 | 5.12 | 4.16 | 4.64 | 4.48 | 4.64 | 4.48 |
| Rutgers (interplanted) | 5.75 | 5.92 | 5.76 | 5.28 | 5.73 | 4.96 | 5.12 | 5.28 | 5 76 | 5.44 |
| Average of Pennheart and Rutgers | 5.28 | 5.52 | 5 28 | 5.36 | 5.36 | 4.48 | 4.89 | 4.96 | 4.96 | 4.89 |

*Significant difference between early harvest variety means: 1945 not significant, 1946 5 per cent = .40 ounces, 1 per cent = .54 ounces.

**Significant difference between late harvest variety means: 1945 not significant, 1946 5 per cent = .32 ounces, 1 per cent = .40 ounces.

†Significant difference between early harvest spacing means: 1945 not significant, 1946 not significant.

‡Significant difference between late harvest spacing means: 1945 not significant, 1946 not significant.

The fruits obtained from the late harvest are in general somewhat smaller than those obtained from the early harvest. Except for this fact the results are very similar to those obtained from the early harvest.

*1946:*—The 1946 data on fruit size for both the early and the late harvest for the several spacings considered are given also in the table. Although there appears to be a trend toward large size fruit in the wider spacings, the differences among the early harvest spacing means fall short of being significant at the 5 per cent level. The mean weight of Pennheart is 5.04 ounces, while the mean weight of Rutgers is 5.68 ounces. The fruit of the latter variety is significantly larger than the fruit of the former. The two varieties behaved in a similar way when interplanted or when planted alone. Again as in 1945, the fruits obtained from the late harvest are somewhat smaller than the fruit obtained from the early harvest. Differences among the spacing treatment means, 4.59 ounces, 4.85 ounces, 5.01 ounces, and 5.07 ounces, are not significant. Rutgers with a mean fruit size of 5.04 ounces, is significantly larger than Pennheart which is 4.56 ounces.

## YIELD

The experimental results obtained on early marketable yield, late marketable yield and total marketable yield in 1945 and 1946

are presented in Tables II and III. Marketable yield includes all fruits which were fairly smooth and fairly free from cracks and other blemishes. All other fruits were called second grade except those that were discarded because they were badly decayed. In 1945 very few fruits were badly decayed; in 1946, however, a significant number of decayed fruit were discarded as a result of a mild outbreak of late blight that occurred late in the season.

TABLE II—THE EFFECT OF PLANT SPACING ON EARLY, LATE AND TOTAL MARKETABLE YIELD IN TONS PER ACRE OF PENNHEART AND RUTGERS IN 1945.

| Variety | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means of Varieties* |
|---|---|---|---|---|---|
| | *Early Harvest* | | | | |
| Pennheart | 7.0 | 5.6 | 4.4 | 3.5 | 5.13 |
| Rutgers | 4.7 | 3.6 | 2.8 | 1.6 | 3.18 |
| Interplanted | 6.6 | 4.6 | 3.4 | 2.2 | 4.20 |
| Means of spacing** | 6.10 | 4.60 | 3.53 | 2.43 | — |
| Pennheart (interplanted) | 7.6 | 5.4 | 4.2 | 3.0 | 5.05 |
| Rutgers (interplanted) | 5.7 | 3.7 | 2.7 | 1.4 | 3.38 |
| Average of Pennheart and Rutgers | 5.9 | 4.6 | 3.6 | 2.6 | 4.18 |
| | *Late Harvest* | | | | |
| Pennheart | 4.6 | 3.6 | 3.4 | 2.5 | 3 56 |
| Rutgers | 14.8 | 12.3 | 10.3 | 9.7 | 11.78 |
| Interplanted | 8.7 | 7.5 | 6.6 | 5.3 | 7.03 |
| Means of spacings† | 9.37 | 7.80 | 6.77 | 5.83 | — |
| Pennheart (interplanted) | 4.0 | 3.0 | 2.1 | 1.7 | 2.70 |
| Rutgers (interplanted) | 13.4 | 12.0 | 11.1 | 9.0 | 11.38 |
| Average of Pennheart and Rutgers | 9.7 | 8.0 | 6.9 | 6.1 | 7.68 |
| | *Total Harvest* | | | | |
| Pennheart | 11.6 | 9.2 | 7.8 | 6.0 | 8.65 |
| Rutgers | 19.5 | 15.9 | 13.1 | 11.3 | 14.96 |
| Interplanted | 15.3 | 12.1 | 10.1 | 7.5 | 11.23 |
| Means of spacings‡ | 15.47 | 13.40 | 10.30 | 8.26 | — |
| Pennheart (interplanted) | 11.6 | 8.4 | 6.3 | 4.7 | 7.75 |
| Rutgers (interplanted) | 19.1 | 15.7 | 13.8 | 10.4 | 14.75 |
| Average of Pennheart and Rutgers | 15.6 | 12.6 | 10.5 | 8.7 | 11.85 |

*Significant difference between means of varieties: Early harvest 5 per cent =.45 ton, 1 per cent =.62 ton. Late harvest 5 per cent =2.83 tons, 1 per cent =4.06 tons. Total harvest 5 per cent = 1.24 tons, 1 per cent =1.68 tons.

**Significant difference between early harvest spacing means: 5 per cent =.56 ton, 1 per cent = .81 ton.

†Significant difference between late harvest spacing means: 5 per cent =1.79 tons, 1 per cent = 2.44 tons.

‡Significant difference between total harvest spacing means: 5 per cent =2.01 tons, 1 per cent = 2.89 tons.

TABLE III—THE EFFECT OF PLANT SPACING ON PERCENTAGE OF SECOND GRADE YIELD OF PENNHEART AND RUTGERS IN 1945.

| Variety | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means of Varieties* |
|---|---|---|---|---|---|
| Pennheart | 44.0 | 44.0 | 40.0 | 39.0 | 41.8 |
| Rutgers | 39.0 | 33.0 | 35.0 | 31.0 | 34.5 |
| Interplanted | 45.0 | 42.0 | 43.0 | 35.0 | 41.3 |
| Means of spacings** | 42.7 | 39.7 | 39.3 | 35.0 | — |
| Pennheart (interplanted) | 45.0 | 45.0 | 44.0 | 38.0 | 43.0 |
| Rutgers (interplanted) | 43.0 | 38.0 | 40.0 | 31.0 | 38.0 |
| Average of Pennheart and Rutgers | 42.0 | 39.0 | 38.0 | 35.0 | 38.5 |

*Significant difference between means of varieties: 5 per cent =2.56, 1 per cent =3.49.

**Significant difference between means of spacings: 5 per cent =2.76, 1 per cent =3.97.

*Early Marketable Yield 1945:*—The marketable yield data for 1945 are presented in Table II. The early yield of Pennheart was considerably greater than that of Rutgers at all spacings while the interplanted plots were intermediate between the varieties in yield. It is of interest to note that the early yields of the varieties when in the interplanted plots were practically the same as when they were grown alone. The mean early yield of Pennheart was 5.13 tons per acre while that of Pennheart when interplanted with Rutgers was 5.05 tons per acre. The difference in yield is not significant. When the yields of Pennheart and Rutgers are added together and averaged they are very similar to those obtained from the interplanted plots.

The early yield was greatly influenced by plant spacing. The mean yield for the 4 feet by 2 feet spacing was 6.10 tons per acre, while the yields for the 4 feet by 3 feet, 4 feet by 4 feet, and 4 feet by 6 feet spacings were 4.60, 3.53, and 2.43 tons per acre respectively. A difference of .56 ton per acre is statistically highly significant; thus the yields at the closer spacings are significantly greater than the yields at the wider spacings. The interaction of spacings and varieties was found to be not significant, showing that in general the two varieties responded in a similar way to the spacing treatment.

*Late Marketable Yield 1945:*—The late yield results are given in Table II also. In the late harvest period Rutgers produced over three times as much marketable yield as Pennheart. Harvest of Pennheart had been discontinued some time before frost and the vines were practically dead. On the other hand, Rutgers produced good pickings up until frost. Production on the interplanted plots was intermediate between Rutgers and Pennheart. The decrease in yield of Pennheart interplanted as compared with Pennheart alone is highly significant, while the yields of Rutgers alone and Rutgers interplanted are not significantly different. The yield from the interplanted plots is practically the same as the yield of the average of Pennheart plus Rutgers.

The differences in late yield due to spacing was found to be highly significant. It was somewhat of a surprise to find that Rutgers gave the greatest yield at the closest spacing, namely 4 feet by 2 feet, since this variety tends to produce large vines and it is generally conceded that it does best when given considerably more than 8 square feet of space. However, vine growth of tomatoes at State College was rather restricted in 1945 and consequently crowding did not occur to any great extent. On the other hand, crowding probably accounts for the fact that Pennheart did not yield so well interplanted as when grown alone.

*Total Marketable Yield 1945:*—It may be noted in Table II that Rutgers produced a much greater yield than Pennheart. It was of special interest to see if interplanted would out-yield the average of Pennheart and Rutgers. The difference in yield of these treatments is only .62 ton per acre and is not statistically significant. The yield of Pennheart, 8.65 tons per acre, is .90 ton per acre greater than that from Pennheart in the interplanted plots, a difference in

yield that is highly significant. A significant interaction of variety and spacing was indicated when Pennheart alone versus Pennheart interplanted was subjected to analysis of variance. This is apparently due to the fact that comparatively poorer yields were obtained from Pennheart interplanted than from Pennheart at the greater spacings. The analysis of variance showed that there was no significant difference between the yields of Rutgers alone and Rutgers interplanted.

Again, as in the case of early and late yield, the effect of spacing on yield was highly significant. Contrary to expectation, Rutgers produced the greatest yields at the closest spacing as did Pennheart.

*Per Cent Second Grade Fruit 1945:*—In classifying the harvest into marketable and second grade, care was exercised to keep the fruit in the marketable class fairly smooth and almost free from cracks and other blemishes. Consequently a rather high percentage of the crop was placed in the second grade class. This fact should not depreciate the value of the data for determination of the effect of plant spacing on the production of marketable (grade 1) fruit since a uniform grading system was used throughout the season. The ratio of the second grade yield to the total yield was obtained and these data are presented in Table III. The percentage of second grade yield in Pennheart and Rutgers is 41.8 and 34.5 respectively. The difference between these figures is greater than 3.49, the difference required to be highly significant. The difference between the percentage of second grade in Pennheart alone versus Pennheart interplanted is significant at the 5 per cent level, and likewise the difference between the percentage of second grade in Rutgers alone versus Rutgers interplanted is significant at the 5 per cent level. In both instances the greater amount of second grade is in the interplanted plots.

The percentages of second grade yield obtained from the spacings 4 feet by 2 feet, 4 feet by 3 feet, 4 feet by 4 feet, and 4 feet by 6 feet were 46.7, 39.7, 39.3, and 35.0 respectively. Since 3.97 is a highly significant difference it may be concluded that plant spacing definitely influences the percentage of second grade yield. There were 7.7 per cent more second grade in the 4 feet by 2 feet spacing than in the 4 feet by 6 feet spacing and it seems reasonable to conclude that the regression of spacing on percentage of second grade is essentially a straight line. From the analysis of variance a nonsignificant F value for interaction of variety and spacing shows that the varieties responded to spacing treatment in essentially a similar manner.

*Early Marketable Yield 1946:*—It may be noted in Table IV that the closer spacings produced much greater yields than did the wider spacings. The difference between the yield of Pennheart alone and Pennheart in the interplanted plot is not significant, nor is the difference between the yield of Rutgers alone and Rutgers in the interplanted plot significant. Since this is true, the yield of the interplanted plot and the average yield of Pennheart and Rutgers are not significantly different.

TABLE IV—THE EFFECT OF PLANT SPACING ON EARLY, LATE AND TOTAL MARKETABLE YIELD IN TONS PER ACRE OF PENNHEART AND RUTGERS IN 1946.

| Variety | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means of Varieties* |
|---|---|---|---|---|---|
| | *Early Harvest* | | | | |
| Pennheart | 2.4 | 1.6 | 1.1 | 0.6 | 1.43 |
| Rutgers | 1.8 | 1.4 | 0.7 | 0.6 | 1.13 |
| Interplanted | 1.9 | 1.4 | 0.9 | 0.5 | 1.25 |
| Means of spacings** | 2.03 | 1.57 | 0.90 | 0.57 | — |
| Pennheart (interplanted) | 2.1 | 1.8 | 1.0 | 0.6 | 1.38 |
| Rutgers (interplanted) | 1.7 | 1.6 | 0.8 | 0.4 | 1.13 |
| Average of Pennheart and Rutgers | 2.1 | 1.5 | 0.9 | 0 5 | 1.28 |
| | *Late Harvest* | | | | |
| Pennheart | 4.6 | 4.0 | 1.1 | 2.1 | 2.95 |
| Rutgers | 6.1 | 6.8 | 6.5 | 4.7 | 6.03 |
| Interplanted | 6.1 | 6.0 | 4.6 | 3.9 | 5.15 |
| Means of spacings† | 5.60 | 5.60 | 4.07 | 3.57 | — |
| Pennheart (interplanted) | 4.6 | 4.0 | 2.2 | 2.1 | 3.23 |
| Rutgers (interplanted) | 8.1 | 8.5 | 6.8 | 5.9 | 7.33 |
| Average of Pennheart and Rutgers | 5.4 | 5.4 | 3.8 | 3.4 | 4.50 |
| | *Total Harvest* | | | | |
| Pennheart | 7.0 | 5.6 | 2.2 | 2.7 | 4.38 |
| Rutgers | 7.9 | 8 2 | 7.2 | 5.3 | 7.15 |
| Interplanted | 8.0 | 7.6 | 5.5 | 4.4 | 6.38 |
| Means of spacings‡ | 7.63 | 7.17 | 4.97 | 4.10 | — |
| Pennheart (interplanted) | 6.7 | 5.8 | 3.2 | 2.7 | 4.60 |
| Rutgers (interplanted) | 9.8 | 10.1 | 7.6 | 6.3 | 8.45 |
| Average of Pennheart and Rutgers | 7.5 | 6.9 | 4.7 | 4.0 | 5.78 |

*Significant difference between means of varieties: Early harvest 5 per cent =.23 ton, 1 per cent =.32 ton. Late harvest 5 per cent =.87 ton, 1 per cent =1.19 tons. Total harvest 1 per cent =.83 ton, 5 per cent =1.13 tons.

**Significant difference between early harvest spacing means: 5 per cent = .39 ton, 1 per cent =.57 ton.

†Significant difference between late harvest spacing means: 5 per cent =.82 ton, 1 per cent = 1.18 tons.

‡Significant difference between total harvest spacing means: 5 per cent =.91 ton, 1 per cent = 1.31 tons.

*Late Marketable Yield 1946:*—The difference in the means of Pennheart and Rutgers is 3.08 tons per acre and is highly significant. The table indicates that highly significant differences occur among the spacing means; it is noteworthy, however, that the yield of Rutgers at the closer spacings varies only slightly but was considerably less at the widest spacing. The interaction of varieties and spacings is not significant. When the yields of the two varieties grown alone and interplanted are compared, it may be noted that better yields were obtained from the varieties when interplanted, especially in the case of Rutgers where the difference in yield is highly significant. The difference in the Pennheart comparison is barely significant.

*Total Marketable Yield 1496:*—The lower part of Table IV gives the total marketable yield. The greatest yield obtained from Pennheart was at the 4 feet by 2 feet spacing. From Rutgers the greatest yield was obtained at the 4 feet by 3 feet spacing with but a slight decrease in yield at the 4 feet by 2 feet spacing. A significantly poorer yield was obtained at the 4 feet by 4 feet spacing and a very considerable reduction in yield at the 4 feet by 6 feet spacing. The yield

of the interplanted plot is as good as Rutgers at the 4 feet by 2 feet spacing, but is considerably less at the wider spacings. The total marketable yields obtained from Pennheart at all of the spacings do not differ significantly from those obtained from corresponding spacings of Pennheart interplanted. On the other hand, Rutgers produced a significantly great yield at all spacings when interplanted than when grown alone. This is probably due to the greater degree of crowding of plants in the Rutgers plot as compared with the crowding in the interplanted plot.

*Percentage of Second Grade Fruit, 1946:*—The percentage of second grade yield was slightly greater in Pennheart than in Rutgers, the difference, however, falls short of being significant (Table V).

TABLE V—THE EFFECT OF PLANT SPACING ON PERCENTAGE OF SECOND GRADE YIELD OF PENNHEART AND RUTGERS IN 1946.

| Variety | 4×2 Ft | 4×3 Ft | 4×4 Ft | 4×6 Ft | Means of Varieties* |
|---|---|---|---|---|---|
| Pennheart | 52.0 | 53.0 | 54.0 | 47.0 | 51.5 |
| Rutgers | 55.0 | 48.0 | 47.0 | 42.0 | 48.0 |
| Interplanted | 50.0 | 46.0 | 49.0 | 43.0 | 47.0 |
| Means of spacing** | 52.3 | 49.0 | 50.0 | 44.0 | — |
| Pennheart (interplanted) | 53.0 | 52.0 | 53.0 | 48.0 | 51.5 |
| Rutgers (interplanted) | 48.0 | 44.0 | 47.0 | 40.0 | 44.8 |
| Average of Pennheart and Rutgers | 53.0 | 51.0 | 51.0 | 45.0 | 50.0 |

*Significant difference between means of varieties: not significant.
**Significant difference between means of spacings: not significant.

The percentage of second grade fruit in Pennheart in the interplanted plot was identical with the amount of second grade fruit in Pennheart when planted alone. While Rutgers shows a slightly greater percentage of second grade fruit than Rutgers in the interplanted plot the difference is not statistically significant.

As in 1945, the smallest percentage of second grade fruit was found in the widest spacing, 4 feet by 6 feet; the differences among the spacing treatment means, however, fall short of being statistically significant. In the case of Rutgers the percentage of second grade yield for the spacings 4 feet by 2 feet, 4 feet by 3 feet, 4 feet by 4 feet, and 4 feet by 6 feet are 55, 48, 47, and 42, respectively. Especially in this variety there appears to be a definite trend in reduction of percentage of second grade yield as the spacing distance is increased and perhaps some significance may be attached to this fact, appreciating, of course, the fact that the differences are statistically not significant.

## Discussion and Conclusion

In this experiment the closer spacings produced the greater yields in both the early and the late harvests in both years of the test. This result had not been anticipated since it is generally believed that spacings as close as 4 feet by 2 feet would result in over crowding and an accompanying reduction in yield, especially in the large vined variety Rutgers. It should be pointed out that at State Col-

lege vine growth is not, as a rule, lush and consequently crowding of tomatoes is not so common at State College as it may be elsewhere in the State. Since this is true, a general recommendation that the closer spacings are best cannot be made.

Lushness of vine growth has been mentioned as a factor that determines the most suitable planting distance for tomatoes. Land value may be another since with high land values the close spacings producing the greater yields would be most practical. In Pennsylvania the control of diseases is another factor of considerable importance with respect to planting distances. In 1947 and again in 1948 late blight caused great damage to the tomato crop in the State. Equipment used to spray potatoes and other crops was adapted to use in the control of the late blight of the tomatoes. This was possible provided the tomato rows were somewhere in the range of between 5 and 6 feet apart. With the wide spacing the plant spacing in the row was reduced to between 2 and 3 feet. Thus the area per plant remained approximately the same as with the 4 by 4 foot spacing previously used. Many growers believe that they are obtaining yields from this new spacing that are just about as good as could be obtained at any other spacing, at least they are satisfield with the 3 feet by 5 feet or 2½ feet by 6 feet spacings, taking into consideration ease of late blight control. Thus, while it is no doubt true that in many instances greater yields could be obtained by closer spacings, a number of factors must be considered carefully in making recommendations to growers. In Pennsylvania at the present time the control of late blight is a factor of such importance that it will be given first consideration, and since the wider spacings facilitate blight control the general recommendations will probably be to continue such wide spacings. In favor of the wide spacing is the fact that a greater percentage of first grade fruit are obtained.

Increases in yield were not obtained by interplanting Rutgers and Pennheart. The 1945 and 1946 seasons tended to favor early production and consequently the possible beneficial effect of interplanting may have been minimized, since one objective of interplanting was to obtain early production from the determinate Pennheart and then a late production from the indeterminate Rutgers resulting in a greater total production per acre.

## Literature Cited


1. Currence, T. M. The interaction between variety, spacing and staking of tomato plants. *Proc. Amer. Soc. Hort. Sci.* 39: 315–318. 1941.
2. Larson, R. E. Tomato experiments on the Chenango soils of Erie County. Paper 1353 Journal Series *Penn. Agr. Exp. Sta.* 1946.
3. ———— and Currence, T. M. The extent of hybrid vigor in $F_1$ and $F_2$ generations of tomato crosses. *Minn. Tech. Bul.* 164. 1944.
4. Parker, M. M. Increasing tomato yields by interplanting. *Proc Amer. Soc. Hort. Sci.* 42: 551–553. 1943.

# Effect of Modified Fertilizer Ratio on Yield of Vegetables[1]

By D. D. Dolan and E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

This experiment was begun in 1933 to study the effect of modifying the proportions of the three common fertilizer nutrients on the yields of two vegetable crops. Crandall and Odland (5, 6) published in separate papers the celery yield data for the first 5 years and the tomato yield data for the first 6 years of the experiment. In 1942, peppers replaced celery as one of the crops and the experiment was continued thus for the next 4 years. The present paper is a report of the combined yield data of all three crops.

Many investigators have studied the effects of nitrogen, phosphorus, and potash, singly and in combinations with varying proportions, on the growth of vegetable crops. In general, it has been found that nitrogen stimulates vegetative growth and gives the greatest increase in size of plant, number of tubers, fruitfulness, and size of seeds (3, 10, 1). Phosphorus promotes rapid early growth and accelerates development of the plants; it is usually responsible for earlier and more prolific flowering, and a resultant increase in yield (8). Potassium generally brings the least response of any of the three main plant nutrients. It has been shown necessary for $CO_2$ assimilation, nitrate reduction in the plant and meristematic activity (11). It aids in nitrogen uptake and is essential to rapid increase in the total dry weight (9). On the other hand in some cases, it delays maturity (1), decreases total dry weight (9) and depresses total yield (8).

It has been pointed out that not only level of fertilization, but also relative balance of the three main ingredients must be given consideration in the nutrition of vegetable crops. Gerdel (7) demonstrated that a well-balanced fertilizer mixture gave the earliest silking, the narrowest silking range and the highest yield of sweet corn. Willcox (12) claims that persistent increase in the amount of fertilizer may depress yields, due to nutrient unbalance and that increased yields are dependent on harmonic balance of nutrients.

Furthermore, it has been shown that crops respond differently to modifications of the ratio of the three main fertilizer ingredients and that omission of one or two of the essential ingredients is expressed in some crops more quickly than in others. Bushnell (2) found that cucumbers were most responsive to nitrogen and phosphorus. Cabbage was more responsive to nitrogen than to phosphorus and the reverse was true with regard to tomatoes. Tomatoes were more re-

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[1]Contribution No. 726 of the Rhode Island Agricultural Experiment Station, Kingston, Rhode Island.

The work here reported was carried on over the period 1933 to 1945. During that period the following succession of cooperators occurred (1) F. K. Crandall and T. E. Odland (2) W. L. Bartholdi (3) R. E. Larson (4) E. M. Anderson and W. L. Marchant, Jr.

Determinations of readily available phosphorus and exchangeable potassium were made through the courtesy of the Department of Agricultural Chemistry.

sponsive to potash than either cucumbers or cabbage. Crandall and Odland reported that celery is more responsive to nitrogen and potash than to phosphorus (5), while tomatoes were more responsive to nitrogen than either of the other fertilizer ingredients (6). However, tomatoes grown with high-nitrogen fertilizer were less solid and had larger seed cavities than fruit grown with medium or low-nitrogen fertilization.

## Materials and Methods

The experimental area consisted of 42 plots 1/63 acre in size on Bridgehampton very fine sandy loam. Each year 21 plots, half of the area, were planted to each of two vegetable crops and their respective positions in the field were alternated from year to year so as to give a 2-year, 2-crop rotation. The 21 plots of each crop were alloted to three replicates of seven different fertilizer treatments as follows: 1, regular 5-10-5; 2, N reduced one-half (2½-10-5); 3, N increased one-half (7½-10-5); 4, P reduced one-half (5-5-5); 5, P increased one-half (5-15-5); 6, K reduced one-half (5-10-2½); and 7, K increased one-half (5-10-7½).

All fertilizers were applied at the rate of 1,500 pounds per acre. In each fertilizer mixture one-fifth of the nitrogen was supplied in an organic form from tankage with approximately one-third of the remainder from nitrate of soda and two-thirds from sulfate of ammonia. The sources of phosphorus and potash were superphosphate and muriate of potash, respectively.

After the crops were removed each year, winter rye was grown as a cover crop. Manure was applied at the rate of 8 tons per acre each spring and the rye was allowed to grow until plowed under in the early part of May.

The experiment was begun with tomatoes on the north half of the field and celery on the south half of the field. In alternate years, the crops were rotated so that celery was on the north half and tomatoes on the south half. This rotation of tomatoes and celery was continued until the end of the 1941 season. In 1942, the same rotation was continued, but celery was replaced by peppers.

This rotation of the crops in alternate years made it difficult to analyze the yield data by ordinary analysis of variance. On the recommendation of Dr. Walter C. Jacob the complete data for each crop was analyzed separately by Yates and Cochran's method of analyzing data from groups of long-term experiments (5, 15).

The varieties of tomatoes, celery, and peppers grown were Pritchard, Golden Plume and Windsor A, respectively. The plants were spaced 3 feet by 4 feet for tomatoes, 3 feet by 6 inches for celery, and 3 feet by 2 feet for peppers. The average date of setting was June 4 for tomatoes, June 9 for celery and June 28 for peppers.

At the end of the experiment, the fertility level in each plot was measured by making determinations of readily available phosphorus by Truog's method and exchangeable potassium. Determinations of pH were also made.

## Results

Analysis of variance revealed several factors of the experiment to be significant. In both tomato and celery data, differences due to the fertilizer treatments were highly significant. In both celery and pepper data, differences due to locations were highly significant, indicating that the soil in the field was not uniform. The south half of the experimental area was more gravely and gave higher yields of celery and peppers. The location effect, however, did not significantly modify tomato yields. In both tomato and celery data, the interaction between treatments and locations was highly significant, indicating that the response to the different treatments varied with the location in the field.

Analysis of pepper yield data revealed that differences due to fertilizer treatments were significant.

Comparisons of the yields obtained from the different fertilizer treatments as shown in Table I may be made by two methods using the least significant difference. Firstly, the high treatment for each nutrient may be compared with the low treatment for the same nutrient. Secondly, each fertilizer treatment, both the high levels and the low levels, may be compared in turn to the standard mixture.

TABLE I—Average Yields Per Acre of Tomatoes, Celery and Pepper With Six Modified Fertilizer Mixtures

| Treatment | Formula | Tomatoes (Bu) | Celery (Trimmed) (Cwt) | Peppers (Bu) |
|---|---|---|---|---|
| Standard mixture | 5–10–5 | 448 | 220 | 221 |
| Low nitrogen | 2½–10–5 | 394 | 203 | 215 |
| High nitrogen | 7½–10–5 | 510 | 231 | 226 |
| Low phosphorus | 5–5–5 | 423 | 208 | 180 |
| High phosphorus | 5–15–5 | 458 | 229 | 215 |
| Low potash | 5–10–2½ | 433 | 212 | 164 |
| High potash | 5–10–7½ | 436 | 245 | 187 |
| Least difference 19:1 | | 24 | 13 | 29 |
| 99:1 | | 31 | 18 | 39 |

Using the first method, it may be observed that both high nitrogen and high phosphorus gave very significant increases in yield of both tomatoes and celery over the corresponding low treatments. High potash very significantly increased the yield of celery, but not tomatoes, over low potash. With peppers, phosphorus was the only nutrient to show an increased yield of the high treatment over the low treatment.

Using the method of comparison with the standard mixture, it may be observed that both low nitrogen and low phosphorus reduced the yield of both tomatoes and celery as compared to the standard. Low phosphorus also reduced the yield of peppers. Low potash reduced the yield of peppers, but not tomatoes or celery. High nitrogen very significantly increased the yield of tomatoes over the standard, but did not significantly affect the yield of celery. With none of the three crops in the experiment did high phosphorus give higher yields than the standard mixture. High potash gave a

very significant increase in yield with celery, was unresponsive with tomatoes and reduced the yield of peppers. The latter is unexplained. It is interesting to note that both low and high potash reduced the yield of peppers below that of the standard mixture.

In general, the pepper yields are low. This may be at least partially accounted for by the late average setting date for peppers which was June 28.

Fertility level measurements at the end of the experiment (Table II) show that phosphorus and potassium content was highest in soils receiving the high level of the respective nutrient and lowest in soils receiving the low level of the respective nutrient. In addition, low-nitrogen apparently brought about an accumulation of both phosphorus and potassium and the low potash treatment caused an accumulation of phosphorus. The pH of the soil was not appreciably affected by the fertilizer treatments.

TABLE II—Average Readily Available Phosphorus, Exchangeable Potassium and pH of Plots Receiving Each of Seven Fertilizer Treatments (Pounds Per Acre)

| Treatment | Formula | Readily Available P | Exchangeable K | pH |
|---|---|---|---|---|
| Standard mixture | 5-10-5 | 280 | 292 | 6.3 |
| Low nitrogen | 2½-10-5 | 340 | 441 | 6.4 |
| High nitrogen | 7½-10-5 | 316 | 280 | 6.2 |
| Low phosphorus | 5-5-5 | 208 | 296 | 6.2 |
| High Phosphorus | 5-15-5 | 368 | 292 | 6.3 |
| Low potash | 5-10-2½ | 324 | 273 | 6.2 |
| High potash | 5-10-7½ | 308 | 363 | 6.2 |

## Summary and Conclusions

Both increasing 50 per cent and decreasing 50 per cent the proportion of nitrogen in the fertilizer gave very significant responses in tomato yields. Low nitrogen gave a significant reduction in celery yields, but not in tomato or pepper yields.

Reducing the phosphorus content of the fertilizer mixture 50 per cent caused significant decreases in yield of all three crops. In no case did increasing the proportion of phosphorus in the fertilizer mixture give a higher yield than that of the regular mixture.

A 50 per cent reduction of potash very significantly decreased the yield of peppers, but not tomatoes or celery. A higher proportion of potash very significantly increased the yield of celery, gave no response with tomatoes and reduced the yield of peppers.

This experiment shows that three vegetable crops respond differently to modifications of the proportion of the three main ingredients in the fertilizer mixture. Notwithstanding, the 5-10-5 fertilizer, which has been recommended and widely used for vegetables, was quite satisfactory in this 13-year experiment. Of supplementary nutrients which might be added, nitrogen is the one most likely to give increased yields. Consequently on Bridgehampton fine sandy loam, greater attention should be given to the nitrogen content of vegetable fertilizers. Side dressing with nitrogen during the grow-

ing season would probably help to maintain the proportion of nitrogen for proper balance of nutrients.

## Literature Cited


1. Brown, H. W., and Pope, H. W. Effect of N, P and K in fertilizers on earliness of cotton. *La. Agr. Exp. Sta. Bul.* 306: 1–15. 1939.
2. Bushnell, J. Relative response of cabbage, tomatoes, cucumbers and sweet corn to fertilizers. *Proc. Amer. Soc. Hort. Sci.* 27: 516–519. 1931.
3. Claypool, L. L. Further studies relative to fertilizer placement of lettuce. *Proc. Amer. Soc. Hort. Sci.* 30: 548–549. 1934.
4. Cochran, W. G. Long-term agricultural experiments. *Supp. Journ. Roy. Stat. Soc.* 6: 104–148. 1939.
5. Crandall, F. K., and Odland, T. E. The response of early celery to fertilizer ingredients. *Proc. Amer. Soc. Hort. Sci.* 36: 523–525. 1938.
6. ———— The response of tomatoes to fertilizer ingredients. *Proc. Amer. Soc. Hort. Sci.* 37: 923–926. 1939.
7. Gerdel, R. W. Effect of fertilizers and date of planting on the physiological development of the corn plant. *Plant Phys.* 6: 695–714. 1931.
8. Hepler, J. R., and Kraybill, H. R. Effect of phosphorus on the yield and time of maturity of the tomato. *N. H. Tech. Bul.* 28: 1–43. 1925.
9. Janssen, George The influence of the K concentration on the culture medium on the production of carbohydrates in plants. *Jour. Agr. Res.* 50: 243–261. 1930.
10. Martin, W. H. et. al. Influence of N, P and K on the number, shape and weight of potato tubers. *Jour. Agr. Res.* 43: 231–260. 1931.
11. Nightingale, G. T., Shermerhorn, L. T., and Robbins, W. R. Some effects of nitrogen deficiency on the histological structure and nitrogenous and carbohydrate constituents of plants. *N. J. Agr. Exp. Sta. Bul.* 499: 1–12. 1930.
12. Willcox, O. W. Yield depression effect of fertilizers and its measurement—report on nutritional unbalance disclosed by field tests. *Jour. Amer. Soc. Agron.* 37: 9–20. 1945.
13. Yates, F., and Cochran, W. G. Analysis of groups of experiments. *Jour. Agr. Sci.* 28: 556–580. 1938.

# Temperature Changes of Prepackaged Vegetables in Refrigerated Cases and on Iced Trays[1]

By ROBERT E. HARDENBURG, *Cornell University, Ithaca, N. Y.*

THE importance of thorough refrigeration of vegetables once they have been harvested is well known. Now that open top refrigerated cases are taking the place of the open counter in more and more produce departments, it appears that refrigeration at the retail level is definitely improving. Interest in the prepackaging of vegetables and in the problems incident to the successful marketing of prepackaged vegetables is still increasing.

Bratley (1) pointed out that when vegetables were packaged in tight materials that retard the transfer of heat, considerable refrigeration must be supplied to offset the slow diffusion of heat from them. He found with green beans that only the bottom layer of packages in a refrigerated case was satisfactorily cooled, if they were at room temperature when put in the case.

It was thought desirable to make further studies with other kinds of vegetables and to include precooling. In the present paper, information on temperature changes of several different kinds of prepackaged vegetables displayed in mechanically refrigerated cases and on ice trays are reported.

## MATERIALS AND METHODS

The studies herein reported were supported partially by funds made available under the Research and Marketing Act (Northeast Region) and partially by a grant from the Grange League Federation. Facilities were made available by the P. and C. Chain stores of Syracuse, New York during the summer of 1947. Temperature measurements were obtained in two stores selling prepackaged produce; one having open top Hussman refrigerated cases, the other ice trays. Green beans, spinach, lettuce, lima beans and Pascal celery were purchased and packaged the same day, and then were refrigerated overnight in a 40 to 45 degree F cold room awaiting delivery. Delivery was made by 10:00 am. In another test, sweet corn, peas and lettuce were purchased, packaged, and delivered all in the same morning with no precooling.

On display in the stores, the packages were piled only two deep, except for sweet corn which was in three layers. The test packages were surrounded by other produce piled to the same height in the Hussman case or on ice trays.

Measurements of temperature were taken with copper-constantan thermocouples, which were inserted ½ inch into the vegetables. Openings through the package for the thermocouples were closed

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with scotch tape. Recordings of the temperature were made at hourly intervals.

The ice trays consisted of 2-by-4-foot metal trays 5 inches deep. Three to 4 inches of crushed ice (½-inch to 1-inch pieces) was placed in each. The packages were arranged directly on the leveled ice surface. Crushed ice was replenished once during the day.

Sweet corn, peas, green beans, lima beans and Pascal celery were packaged in paperboard trays and then overwrapped in 300 MSAT cellophane. Lettuce was merely wrapped in cellophane, while the spinach was packaged in cellophane bags.

The refrigeration tests of prepackaged vegetables in the cases and on the ice trays were not done the same day, but on successive days, September 10 and 11, 1947. The store temperatures averaged exactly the same on both days, 84 degrees F.

## Results and Discussion

Non-precooled lettuce overwrapped in cellophane and placed in a refrigerated case that averaged 43 degrees F, cooled from 79 degrees F to 55 degrees F in 4 hours and to 50 degrees F in 8 hours. When sweet corn was packaged four ears to a tray and overwrapped in cellophane, the bottom packages were cooled from an original temperature of 81 degrees F down to 61 degrees F in 4 hours and to 54 degrees F in 8 hours. When sweet corn packages were piled up, as they would be in a store with a considerable sales volume, less refrigeration was obtained. A second layer of prepackaged corn directly above the lower was cooled to only 67 degrees F in 4 hours and to 61 degrees F in 8 hours. A third layer meanwhile cooled to only 70 degrees F in 4 hours and to 65 degrees F in 8 hours. These upper packages received little refrigeration, even though they were all within 6 inches of the coldest part of the case. In a similar test with prepackaged peas, the lower package changed from 82 degrees F, when put in the case, to 66 degrees F at 4 hours and then to 57 degrees F after 8 hours under refrigeration. A second package above the lower changed from 82 degrees F down to 74 degrees F in 4 hours and to only 69 degrees F after 8 hours under refrigeration.

The temperature tests with precooled prepackaged vegetables were conducted to determine how effective refrigerated cases and ice trays were in holding vegetables at a satisfactory low temperature while being marketed. These results are shown in Tables I and II. In considering these results, it should be pointed out that all the kinds of vegetables were not at the same identical temperature at the beginning of the test, as is shown in the tables, even though they were all in the same produce cooler the preceding night. After 5 hours in the refrigerated case, the average temperature of the bottom packages of five kinds of vegetables was 51 degrees F. This represents an increase of only 3 to 5 degrees above their precooled temperature. A second layer of packages of the same five kinds of vegetables placed above the first averaged 59 degrees F after 5 hours. This indicates an average spread of 8 degrees F in the amount

TABLE I—TEMPERATURE CHANGES OF PRECOOLED PREPACKAGED VEGETABLES IN A REFRIGERATED CASE (50 DEGREES F)*

| Vegetable | Position | Start | 1 Hr | 2 Hrs | 3 Hrs | 4 Hrs | 5 Hrs | Temperature Change in 5 Hrs |
|---|---|---|---|---|---|---|---|---|
| Green beans | Lower package | 48 | 48 | 48 | 50 | 50 | 50 | +2 |
| | Upper package | 48 | 50 | 52 | 54 | 55 | 55 | +7 |
| Lima beans | Lower package | 48 | 52 | 52 | 52 | 52 | 52 | +4 |
| | Upper package | 48 | 55 | 57 | 59 | 59 | 61 | +13 |
| Pascal celery | Lower package | 46 | 46 | 48 | 48 | 48 | 48 | +2 |
| | Upper package | 46 | 50 | 51 | 52 | 54 | 54 | +8 |
| Lettuce | Lower package | 46 | 49 | 50 | 50 | 51 | 51 | +5 |
| | Upper package | 46 | 51 | 55 | 57 | 58 | 59 | +13 |
| Spinach | Lower package | 48 | 52 | 54 | 54 | 54 | 54 | +6 |
| | Upper package | 48 | 59 | 61 | 63 | 64 | 64 | +16 |

*Room temperature averaged 84 degrees F.
Precooled in a 40 to 45 degree F produce cooler overnight.

TABLE II—TEMPERATURE CHANGES OF PRECOOLED PREPACKAGED VEGETABLES ON ICED TRAYS*

| Vegetable | Position | Start | 1 Hr | 2 Hrs | 3 Hrs | 4 Hrs | 5 Hrs | Temperature Change in 5 Hrs |
|---|---|---|---|---|---|---|---|---|
| Green beans | Lower package | 46 | 53 | 54 | 55 | 57 | 55 | +9 |
| | Upper package | 48 | 63 | 68 | 74 | 76 | 79 | +31 |
| Lima beans | Lower package | 46 | 52 | 52 | 55 | 58 | 59 | +13 |
| | Upper package | 48 | 63 | 68 | 73 | 75 | 77 | +29 |
| Pascal celery | Lower package | 48 | 54 | 54 | 55 | 55 | 56 | +8 |
| | Upper package | 48 | 65 | 70 | 75 | 77 | 79 | +31 |
| Lettuce | Lower package | 43 | 49 | 52 | 55 | 57 | 58 | +15 |
| | Upper package | 45 | 63 | 71 | 76 | 79 | 80 | +35 |
| Spinach | Lower package | 41 | 45 | 50 | 54 | 55 | 55 | +14 |
| | Upper package | 43 | 61 | 70 | 77 | 79 | 79 | +36 |

*Room temperature averaged 84 degrees F.
Precooled in a 40 to 45 degree F produce cooler overnight.

of refrigeration received between lower and upper packages after 5 hours in a refrigerated case.

Crushed ice trays were not as effective as refrigerated cases in holding precooled packaged vegetables. The average temperature of the five kinds of packaged vegetables directly on the ice was 57 degrees F after 5 hours. This represents an increase in temperature of 9 to 15 degrees above the precooled temperature. The layer of packages above the first on the ice trays rapidly increased in temperature, and appeared to be receiving little refrigeration from the ice. After 5 hours, these packages averaged 79 degrees F, while the mean store temperature was 84 degrees F. The average spread in temperature between those packages on the ice and the second layer of packages after a 5-hour test period was 22 degrees F. This difference developed even though the upper packages were less than 6 inches from the ice. The differences observed between the mechanical refrigerated cases and the ice trays may be largely attributed to the construction of the ice trays, which trap very little cold air. The second layer of packages on the ice trays extended well above the sides of the tray, whereas the mechanical cases were much deeper and gave greater protection against the loss of cold air.

As refrigeration of prepackaged vegetables before delivery to retail stores appears desirable, tests were made to determine the most rapid rate of cooling packages in a 35 degree F produce cold room. Wax beans and peas were tested using three arrangements of packages: individual packages on shelves, 12 packages in a sealed shipping case, and 12 packages in an open shipping case. Leaving the individual packages out of the shipping case until just before delivery time proved to be the most rapid method of precooling the packaged vegetables. Single packages of wax beans cooled from 70 degrees F to below 50 degrees F in 2 hours, and to 42 degrees F in 5 hours. The vegetables in the shipping case with the top left open cooled to 50 degrees F in 5 hours; while those in the sealed shipping case cooled to a temperature of 54 degrees F in the same period, but to only 63 degrees F in 2 hours. The same tests with prepackaged peas gave approximately identical results.

Results of the above studies lead to the recommendation, that after delivery of the precooled packages to retail stores having refrigerated cases, that maximum use be made of the bottom compartments of the cases for storage. To insure better refrigeration for prepackaged vegetables, only a single layer of packages should be on display in the upper part of the case at any time.

## Summary

Prepackaged sweet corn and peas, which had not been precooled prior to displaying for sale in a refrigerated case, were slow to cool. Only the bottom layer of packages in the case cooled below 60 degrees F during an 8-hour test.

Temperature changes of five kinds of precooled packaged vegetables were recorded with thermocouples, when displayed in refrigerated cases or on ice trays. A refrigerated case was quite effective in holding the temperature of produce low, particularly the bottom layer of packages. Ice trays as described were not as satisfactory for refrigerating prepackaged vegetables as a refrigerated case. Packages other than those directly on the ice surface appeared to receive little refrigeration.

## Literature Cited

1. Bratley, C. O. Refrigeration of prepackaged fruits and vegetables. *Refrigerating Engineer.* December, 1946.

# Objective Methods for Measuring Quality Factors of Raw, Canned, and Frozen Asparagus[1]

By AMIHUD KRAMER, I. C. HAUT, and L. E. SCOTT, *University of Maryland, College Park, Md.*, and L. E. IDE, *U. S. Department of Agriculture, Washington, D. C.*

THE important factors of quality in asparagus are color, flavor, and freedom from fibrousness. Although there is practically nothing in the literature on the objective determination of asparagus color or flavor, several methods for determining the fibrousness or toughness of raw and canned asparagus have been suggested.

Working with raw asparagus, MacGillivray (3) used the conventional fruit pressure tester with ⅛-inch plunger and found that resistance increased with duration of season and distance from the tip. Lee and Sayre (2) reported a correlation of .9000 between tenderometer readings and organoleptic tests. The tenderometer readings were obtained by filling the sample space with 4.5 inch stalks.

Lee (1) recommended the use of alcohol insoluble solids content as a measure of toughness of frozen asparagus, suggesting that samples having more than 4.35 per cent A.I.S. be considered fancy, and those lower than 4.04 per cent, off grade. Smith and Kramer (5) presented a rapid method for determining the fibrous materials in canned green asparagus, and showed that the fiber content increases rapidly beyond the natural snapping point of the stalk. Values obtained by this method were not affected by various canning procedures. Fiber of fresh and frozen asparagus may be determined by the same method if it is preceded by a cooking treatment. Wilder (8) developed an instrument called the "Fiberometer" for measuring the fibrousness of canned asparagus. The instrument consists of a stainless steel wire to which a 3-pound weight is attached. A stalk is considered tender to the point farthest from the tip that the wire will cut.

The existing standards of the United States Department of Agriculture are almost entirely subjective in that they rely primarily on the judgment of a trained inspector. U. S. Standards for raw green asparagus include only the factor of color and size with the exception of factors that may be considered as defects. The color factor has no definition except a statement that a given length of the stalk must be "green" (6). U. S. Standards for canned asparagus are based on the factors of clearness of liquor, color, absence of defects, and tenderness. The color factor is not defined, except for the statement that maximum score may be given to a product that possesses a "bright, typical color". The tenderness factor is not defined except by statements to the effect that noticeable fibers may not be present in a given proportion of the stalks (7).

## GENERAL METHODS AND MATERIALS

*Series I:*—Asparagus stalks were cut and placed in field boxes on

[1]Scientific paper No. A230, Contribution No. 2160, of the Maryland Agricultural Experiment Station (Department of Horticulture). Partial support from Regional Research and Marketing Act funds (Project NEM3).

the afternoon of May 5, and held overnight at 32 degrees F. They were then cut to a uniform 9-inch length, and bunched. One lot was analyzed immediately, and the remainder were placed in pans containing water which covered the butts of the stalks. The pans were then distributed into storage chambers which were held at the following temperatures: 32, 50, 68, 86 degrees F, and lots were removed from each storage chamber for analysis and preparation of canned and frozen samples at 1-, 3-, 5-, and 7-day intervals. The following four samples were prepared from each lot: (a) tips consisting of the upper 4.5 inches of stalk, (b) first cuts consisting of the 4.5- to 6-inch segment, (c) second cuts consisting of the 6- to 7-inch segment, and (d) snapped portion of the stalk. The latter was done by carefully bending the stalk so that it was allowed to snap at the natural snapping point. This series consisted of 48 samples.

*Series II:*—This series was prepared in a similar manner, except that the material was cut to a uniform length, segregated according to size, bunched, and packed according to the usual procedure for shipment to the fresh market immediately after harvest. Also, separate samples were prepared of small and large stalks. Additional samples were also prepared of the material beyond the snapped portion. This series consisted of 91 samples.

*Series III:*—These samples were prepared from material made available at canning and freezing plants in New Jersey and Delaware, and varied in size, and in the proportion of the stalks that were green or purple or white, and duration of storage under commercial storage conditions. This series consisted of 61 samples.

*Organoleptic Determinations:*—Grades on the raw product were provided by an official grader of the Production and Marketing Administration.

Organoleptic scores on the processed samples for color, fiber, and flavor were provided by a judging panel of six technologists who represented the Department of Agriculture, Industry, and the marketing and horticulture departments of the University of Maryland. The members of the panel were asked to score the samples for color on a scale of 10, where 1 indicated white, 2 borderline white-green, to 10 for the best deep, bright green color. A score of 1 for fibrousness indicated woody, inedible material, 2 borderline edible, 3 excessively fibrous but edible, to 10 for entirely free of fiber. Flavor was indicated by the descriptive terms of excellent 10, good 8, fair 6, poor 4, and off flavor 2.

*Canning and Freezing:*—Canned samples were prepared by blanching for 2½ minutes in 190 degrees F water, cooling, filling into no. 1 or no. 2 cans, adding hot 2 per cent brine, closing, and processing for 25 minutes at 240 degrees F.

Frozen samples were prepared by blanching for 2½ minutes at 190 degrees F, cooling, filling into cellophane-lined cartons, sealing, and freezing overnight at —20 degrees F. The following day the samples were moved to a chamber held at 0 degrees F, where they remained until removed for analysis. For the organoleptic determinations, these

samples were placed in boiling water and cooked for 8 minutes after the second boil.

## Procedures and Results

### COLOR

*Preliminary Studies:*—The possibility of developing a color method based on the colorimetric evaluation of asparagus pigment extracts was investigated as follows:

Transmission curves of acetone extracts of asparagus pigment were obtained by the use of a Beckman spectrophotometer, and presented in Fig. 1, indicating that good differentiation may be obtained at the wave length of 665 mμ for the green pigment. The data in Table I

TABLE I—Per Cent Transmittance at 665 Mμ Obtained by the Use of Different Solvents for Extracting Asparagus Pigment

| Solvent | Transmittance (Per Cent) |
|---|---|
| Acetone | 65.0 |
| Ethanol | 72.2 |
| Ethyl ether | 80.0 |
| Petroleum ether | 91.5 |

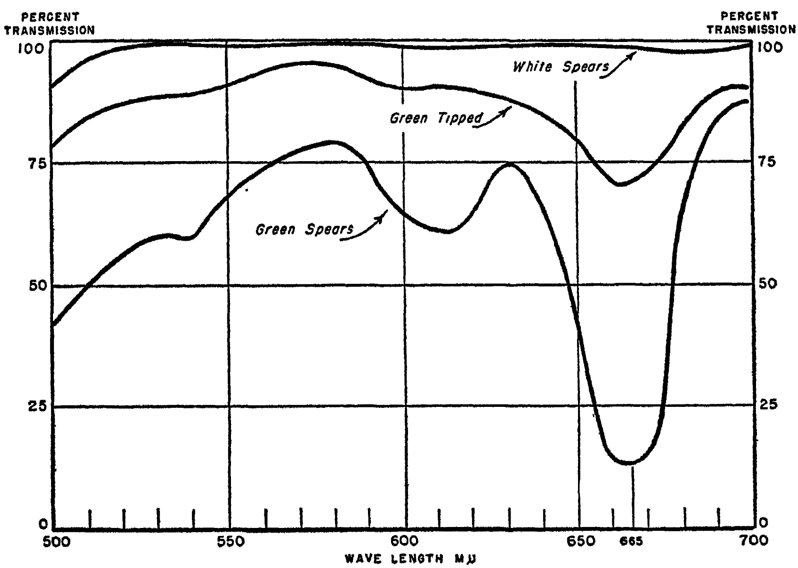


Fig. 1. Transmission curves of acetone extracts of asparagus spears varying in green pigment.

indicate that acetone is the most efficient extracting agent. The following samples were prepared in order to determine whether such an extraction method reflects visual color values. Asparagus stalks were cut into 1 inch pieces. These pieces were then carefully sorted visually into nine lots, lot no. 1 consisted of the greenest samples, and lot no. 9

of white pieces. Lot no. 8 consisted of pieces that were borderline between white and green, and lots 2 to 7 consisted of pieces that were gradually lighter green in color. When these samples were extracted with acetone and measured for their green pigment transmittance, a practically perfect correlation was obtained, showing that this method of color determination agreed closely with organoleptic evaluations of asparagus color (Table II).

TABLE II—COMPARISON OF ORGANOLEPTIC COLOR VALUES AND GREEN PIGMENT CONTENT

| Organoleptic | Transmittance (Per Cent) | | Chlorophyll (Ppm) |
|---|---|---|---|
| | Beckman | Leitz | |
| Greenest | | | |
| 1. | 30.5 | 58 | 144 |
| 2. | 35.0 | 61 | 126 |
| 3. | 45 1 | 67 | 95 |
| 4. | 58.0 | 74 | 64 |
| 5. | 60.4 | 76 | 60 |
| 6. | 69.3 | 81 | 43 |
| Light-green 7 | 73.6 | 83 | 36 |
| Border 8 | 84.1 | 89 | 19 |
| White 9 | 97.5 | 98 | 3 |

*The Method:*—The following method, developed during the preliminary studies, was used to analyze all of the samples described in the above three series, in the fresh, canned, or frozen state.

1. Blend 100 grams of asparagus with 100 grams of water in a Waring blendor, to a uniform pulp.
2. Weigh 20 grams of the above mixture, and transfer to the cup of a Waring blendor with about 70 ml acetone, and blend for exactly 5 minutes.
3. Transfer to a 100 ml graduated cylinder, make up to 100 ml with acetone.
4. Stir the mixture in the cylinder thoroughly and transfer part to a centrifuge tube, and centrifuge for about 10 minutes at 2000 rpm.
5. Measure transmittance of the clarified pigment solution in a suitable instrument at the spectral band centered about 665 mμ.
6. Convert per cent transmittance to parts per million of chlorophyll.

The color instrument should be standardized with a known solution of cholorphyll dissolved in acetone. The Beckman spectrophotometer provides a wide range of values because of the possibility of narrowing the band of light to 5μ. or less. However, it is not absolutely necessary to use this or any spectrophotometer, since the chlorophyll content in asparagus is sufficiently high so that any filter type photoelectric colorimeter may be suitable, provided the light source is strong enough, and the filter is sufficiently narrow and centered about the wave length of 665 mμ. Since the Leitz photoelectric colorimeter met these requirements it was used as an alternative instrument in these studies, and was used solely in the field with entirely satisfactory results. A com-

parison of values obtained on these two instruments and their relation to cholorophyll values are presented in Table II.

*Discussion of Results:*—No attempt was made by the official grader to determine relative greenness of asparagus samples from day to day. In general it appeared that the objective values were closely related to organoleptic color evaluations. Although the intensity of the green color of raw asparagus may be important, the determination of what is and what is not "green" is even more important. Growers of asparagus often question just where the "green" ends and the "white" begins, especially during cool weather, when the intermediate zone may be purple. Since the objective method measures the green pigment only, independently of the presence of other pigments, this point could be determined easily, and was found to be at about 10 parts per million of chlorophyll, or in terms of transmittance at 665 mμ, 91 per cent for the Beckman spectrophotometer, and 94 per cent for the Leitz photoelectric colorimeter. Thus a segment of asparagus that contains less than 10 ppm chlorophyll, may be considered white. In regard to the confusing purple zone, these data indicate that in general, the green pigment starts about 1 inch in the direction of the tip from the basal point at which the purple color begins.

The next question to be determined was to what extent will objective measurements of the green pigment of the raw asparagus reflect the intensity of the color of the canned and frozen product. Consequently, the green pigment values of the raw asparagus calculated in terms of ppm chlorophyll were correlated with organoleptic ratings of the canned product. The resultant correlation of .69 indicated that although the correlation is highly significant, it is not sufficiently high to be used with confidence for prediction purposes. A closer examination of the data indicated that the factor of duration of storage was largely responsible for reducing what might otherwise have been a satisfactory correlation. Apparently the loss in green pigment occurring in the raw product as a result of storage was not reflected in the organoleptic ratings of the canned product. Thus for example a sample of asparagus which was analyzed immediately after harvest contained 195 ppm chlorophyll. Upon holding for 4 days at 70 degrees F, the cholorophyll content of this material was reduced to 93 ppm. Upon canning, the organoleptic values for both of these samples were similar. Thus when the samples were grouped on the basis of duration of storage, the correlations for each group were improved considerably, and were quite satisfactory as shown in Table III.

The equally high correlation between the organoleptic values for the

TABLE III—CORRELATION COEFFICIENTS BETWEEN ORGANOLEPTIC RATINGS OF CANNED ASPARAGUS, AND OBJECTIVE COLOR VALUES FOR RAW AND CANNED ASPARAGUS

| | |
|---|---|
| Organoleptic Ratings × Raw Color | |
| All samples | 0.69 |
| 3 day storage only | 0.87 |
| 5 day storage only | 0.89 |
| 7 day storage only | 0.90 |
| Organoleptic Ratings × Canned Color | |
| All samples | 0.90 |

canned samples and the objective color determinations for the canned samples indicate that the difference between the color of the canned and raw samples is not merely a visual phenomenon, but an actual differential loss in green pigment as a result of storage and processing. It thus appears that the greater the loss of green pigment in raw asparagus as a result of storage, the smaller the further loss incurred during processing. This is illustrated in Fig. 2 for the samples of stalks that were prepared in series I.

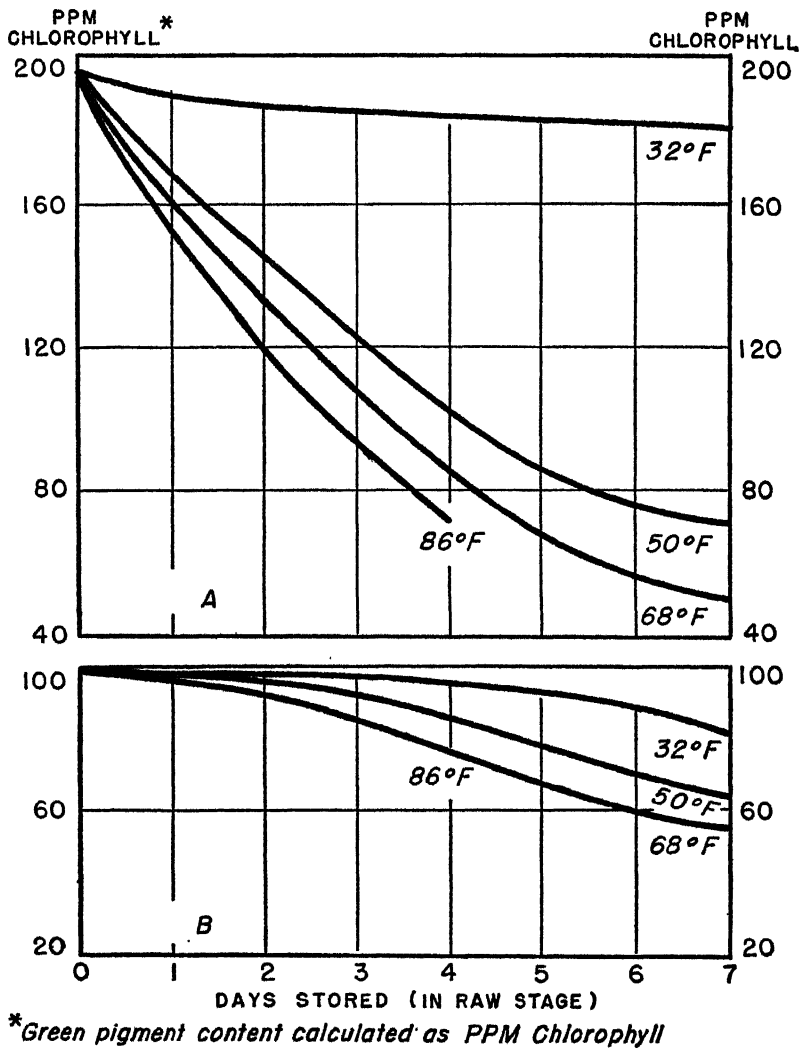


FIG. 2. Effect of duration and temperature of storage of raw asparagus on the green pigment content of (A) raw and (B) canned asparagus.

This differential effect of storage of the raw product on color values of raw as compared to canned asparagus was further substantiated by analyzing the data in series I and II by the variance method. The results are presented in Table IV, and show that whereas there are

TABLE IV—EFFECT OF PLANT PARTS, STORAGE DURATION AND TEMPERATURE ON GREEN PIGMENT CONTENT OF RAW ASPARAGUS, AND ORGANOLEPTIC RATINGS OF CANNED ASPARAGUS

| | Series I | | Series II | |
|---|---|---|---|---|
| | Green Pigment (Ppm Chlor.) | Organoleptic | Green Pigment (Ppm Chlor.) | Organoleptic |
| | *Effect of Plant Parts* | | | |
| Tips | 124 | 8.6 | 129 | 9.2 |
| 1st cut | 59 | 5.9 | 66 | 7.1 |
| 2nd cut | 46 | 4.3 | 57 | 6.3 |
| 3rd cut | — | — | 46 | 5.4 |
| Snaps | 119 | 7.7 | 102 | 8.6 |
| "F" value | 29.9† | 55.3† | 52.0† | 41.6† |
| | *Effect of Storage Duration* | | | |
| 1 day | 129 | 6.9 | 88 | 7.3 |
| 3 days | 119 | 6.8 | 90 | 7.5 |
| 5 days | 64 | 6.3 | 79 | 7.6 |
| 7 days | 48 | 6.5 | 62 | 7.5 |
| "F" value | 35.3† | 0.9 | 8.7† | 0.4 |
| | *Effect of Storage Temperature* | | | |
| 32 degrees | 105 | 6.5 | 84 | 7.6 |
| 50 degrees | 88 | 6.7 | 76 | 7.3 |
| 68 degrees | 91 | 6.7 | — | — |
| 86 degrees | 78 | 6.3 | — | — |
| "F" value | 2.9* | 0.2 | 2.8 | 2.3 |

*Significant at odds 19:1.
†Significant at odds greater than 99:1.

large significant differences in both series as a result of storage duration for the chlorophyll content of the raw asparagus, there is no significant difference between organoleptic ratings for the canned product as a result of these same storage treatments of the raw product.

Whereas the effect of temperature of storage is of possible significance in its effect on chlorophyll content of the raw stock, there is no significant effect of this factor on the organoleptic values of the canned product.

The effect of the portion of the stalk, on the other hand, is equally significant for both the chlorophyll content and the organoleptic ratings.

Fig. 3 illustrates the nature of the relation between organoleptic values and cholorphyll content of canned asparagus. The approximately logarithmic relationship also indicates that cholorphyll values beyond 75 ppm are not easily recognized organoleptically so that there is little advantage to attempt to establish color grades of canned asparagus in that range.

The relation of the color as indicated by green pigment content of the raw asparagus to the canned, and frozen product before and after cooking is presented in Table V. It is apparent that both the freezing and the cooking processes have a detrimental effect on color retention.

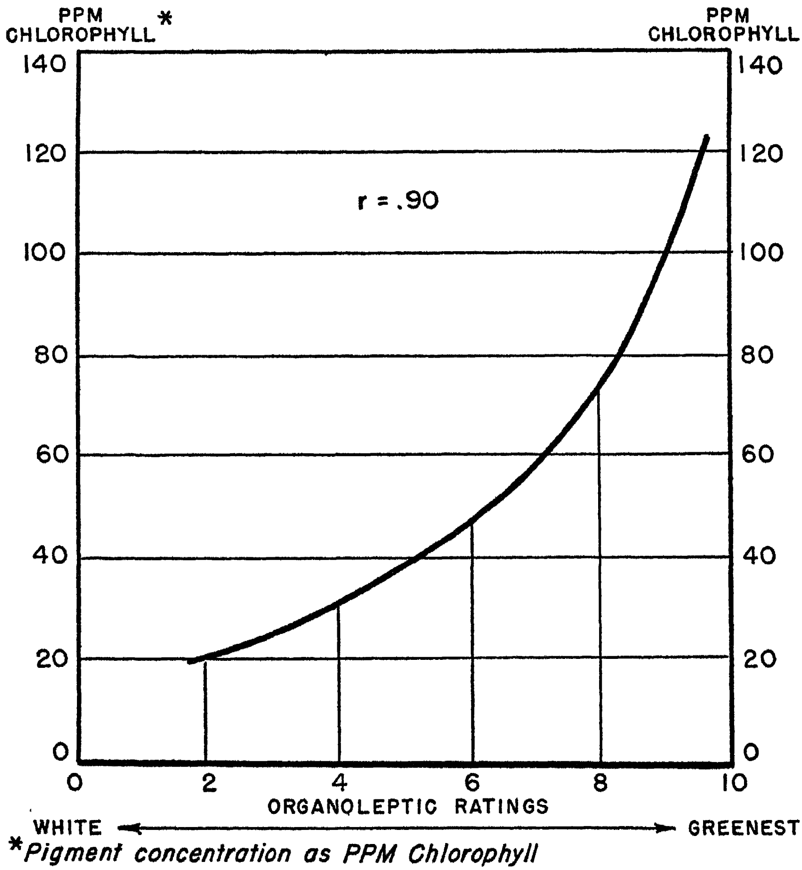


FIG. 3. Relation of organoleptic ratings to green pigment content of canned asparagus.

TABLE V—EFFECT OF CANNING, FREEZING AND COOKING OF THE FROZEN PRODUCT ON GREEN PIGMENT CONTENT OF ASPARAGUS

| Storage Days | Degrees F | Green Pigment | | (Ppm Chlorophyll) | |
|---|---|---|---|---|---|
| | | Raw | Frozen | Frozen and Cooked | Canned |
| 2 | 32 | 182 | 143 | 106 | 92 |
| 2 | 50 | 142 | 118 | 116 | 98 |
| 2 | 68 | 204 | 121 | 102 | 81 |
| 2 | 86 | 107 | 113 | 87 | 96 |
| 4 | 32 | 185 | 131 | 105 | 96 |
| 4 | 50 | 79 | — | — | 81 |
| 4 | 68 | 93 | 104 | 85 | 72 |
| 4 | 86 | 74 | 74 | 80 | 77 |
| 6 | 32 | 180 | 130 | 120 | 82 |
| 6 | 50 | 70 | 102 | 92 | 63 |
| 6 | 68 | 47 | 85 | 75 | 55 |

## Fibrousness

*Preliminary Studies:*—Since the fiberometer (8) could not be used on raw asparagus, and the toughness of individual stalks could not be measured on the tenderometer (2), several instruments were constructed for the purpose of recording the resistance to cutting provided by asparagus stalks varying in degree of fibrousness. Two instruments were retained on the basis of preliminary trials. One is an adaptation of the pressure tester commonly used for measuring the firmness of fruits (Fig. 4), where the plunger was replaced by a piece of stainless steel .017 inch thick. The other is an instrument with a similar cutting arrangement, but the pressure required to cut through the sample is recorded on a gauge (Fig. 5). The results with the two instruments are similar, except that the gauge instrument tends to provide somewhat lower values for tender asparagus.

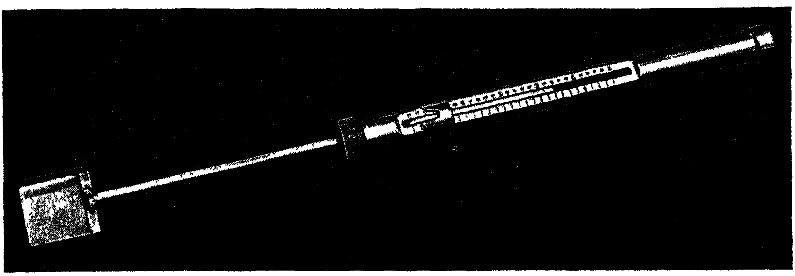

Fig. 4. Adaptation of the pressure tester for measuring fibrousness of raw asparagus.

Sixty-six samples were prepared by cutting 1-inch pieces of asparagus stalks in the middle with the above instruments and thus sorting them into series of samples in terms of pressure and diameter size. These same samples were then rated organoleptically, and analyzed for fiber content. The resultant correlations are presented in Table VI, and indicated that there is generally good agreement between fiber content, pressure values, and organoleptic ratings. When correlations were obtained for different sizes separately, they were invariably higher, showing that the diameter of stalk was a significant factor, particularly, in the relation of pressure readings to organoleptic evaluations of fibrousness.

*Methods:*—The pressure readings were obtained by the use of one or both of the instruments described above (Figs. 4, 5). A minimum

TABLE VI—Correlations From the Ranks Between Pressure Readings, Fiber Content, and Organoleptic Values for Fibrousness of Asparagus Cuts

| | Pressure × Organoleptic | Fiber × Organoleptic | Pressure × Fiber |
|---|---|---|---|
| All cuts | 82 | 83 | 82 |
| Small only | 90 | 85 | 86 |
| Large only | 88 | 86 | 88 |

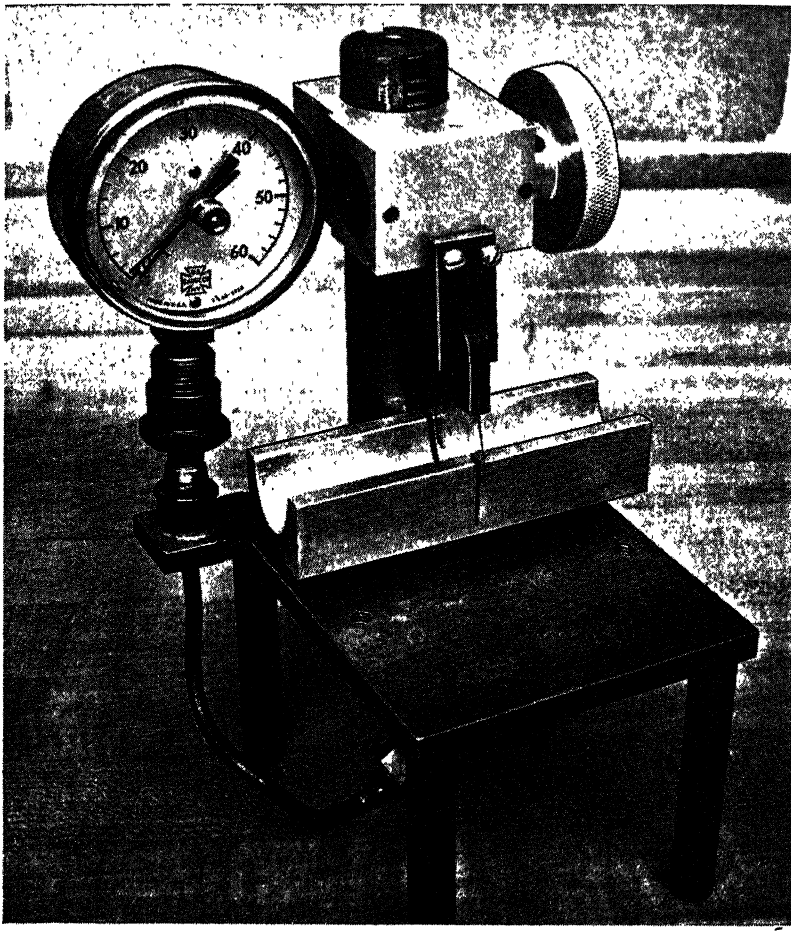


FIG. 5. A gauge instrument developed for measuring fibrousness of raw asparagus.

of 10 readings were obtained for each sample, and the average value was used in the correlation analyses. For the tips and snapped stalks, the pressure reading was obtained about ½ inch from the butt end of the stalk. For the samples of cuts, the pressure reading was obtained about the middle of the length of the cut. Pressure readings were grouped according to stalk diameter classifications.

Fiber determinations were made according to the method described by Smith and Kramer (5).

*Discussion of Results:*—Since the official grades for raw asparagus consist of color and defects only, no official grade could be assigned to the fibrousness of the raw material; however, it was generally ob-

served that there was good relationship between apparent fibrousness and pressure readings, since invariably the pressure readings tended to increase with increasing distance from the tip, and the readings slightly above the natural snapping point of the stalks were invariably between 6 and 8 pounds, depending on the size of the stalk. On the other hand, pressure readings beyond this snapping point increased rapidly to as high as 50 pounds (4).

The correlation coefficient between pressure readings on the raw asparagus and organoleptic ratings for fibrousness on the canned product resulted in a value of .78, which though highly significant and promising, is not sufficiently high to indicate that the pressure readings on the raw product are entirely satisfactory in predicting the fibrousness of the canned product. Upon closer analysis, it appeared that the lack of better correlation was due primarily to the effect of size as indicated by the diameter of the stalk. Thus when the samples were first segregated by size, the correlations were .82 for the small, and .87 for the large stalks. Considering the tremendous variability obtaining among stalks of asparagus, and the fact that the pressure readings for the stalks were taken differently from those taken for the cuts, these correlations indicate that if separate scales will be established for stalks of different diameters, pressure readings on the raw

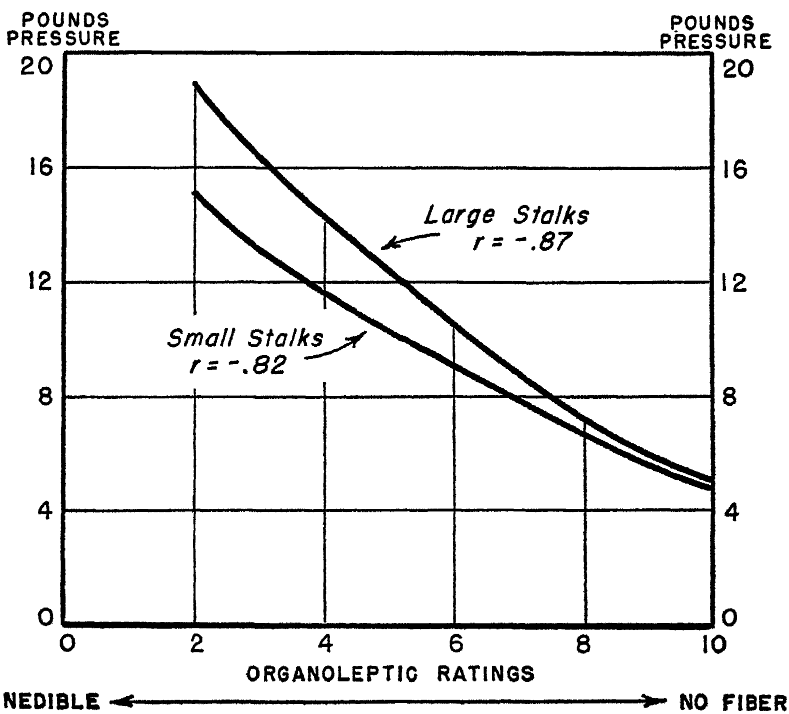


FIG. 6. Effect of stalk diameter to the relation between organoleptic ratings on canned asparagus and pressure readings on raw asparagus.

product will indicate with sufficient accuracy the fibrousness of the canned product. The regression lines in Fig. 6 illustrate the effect of the different stalk diameters on the relation between the pressure readings and organoleptic ratings.

The fiber content of the raw and canned asparagus is identical, since the raw sample must be cooked before the fiber test can be applied, and the amount of cooking has no effect on the results (5). The data presented are fiber determinations on the canned samples, but the results may be applied to the raw product as well; however, since the determination of quality for the raw stock should be as rapid as possible, it was hoped that the pressure reading would serve as the routine evaluation of fibrousness for the raw stock, with the fiber test serving

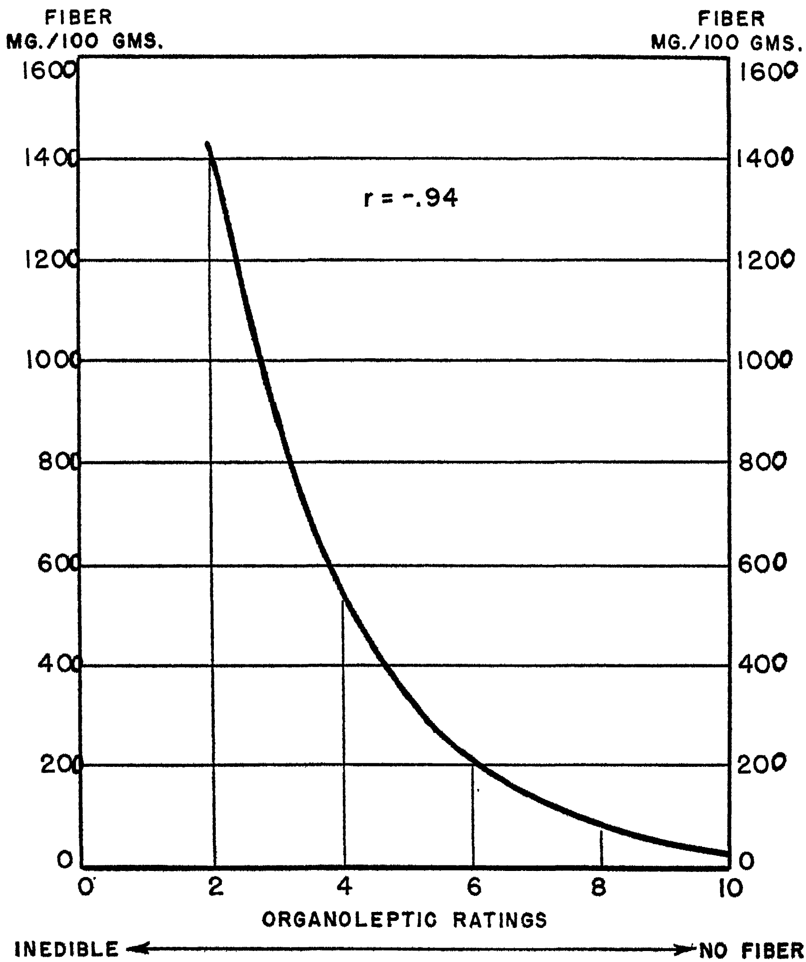


FIG. 7. Relation of fiber content to organoleptic ratings of canned asparagus.

primarily as a check, especially on the final quality of the finished product.

The correlation between fiber content and fibrousness as determined organoleptically is shown in Fig. 7. The correlation coefficient of .94 shows exceptionally good agreement between these factors. No effect of size or other factor was noted. This logarithmic relationship also suggests the probability that the significant fiber content is in the range of 100 to 800 mg/100 gm, that is, values below 100 mg are practically equivalent to no fiber, while values above 800 are all indicative of excessive fiber to such a degree that doubling the fiber content beyond that point affects organoleptic grades only slightly.

There remains the correlation between the pressure readings on the raw product and fiber content, so that the entire evaluation of fibrousness may be made on an objective basis. This relationship is also affected by size as measured by diameter of stalk. The relationship of pressure readings to fiber content as affected by size is shown graphically in Fig. 8.

## Freshness

Although much importance is frequently ascribed to the factor of freshness, there are no data available to show definitely that factors of

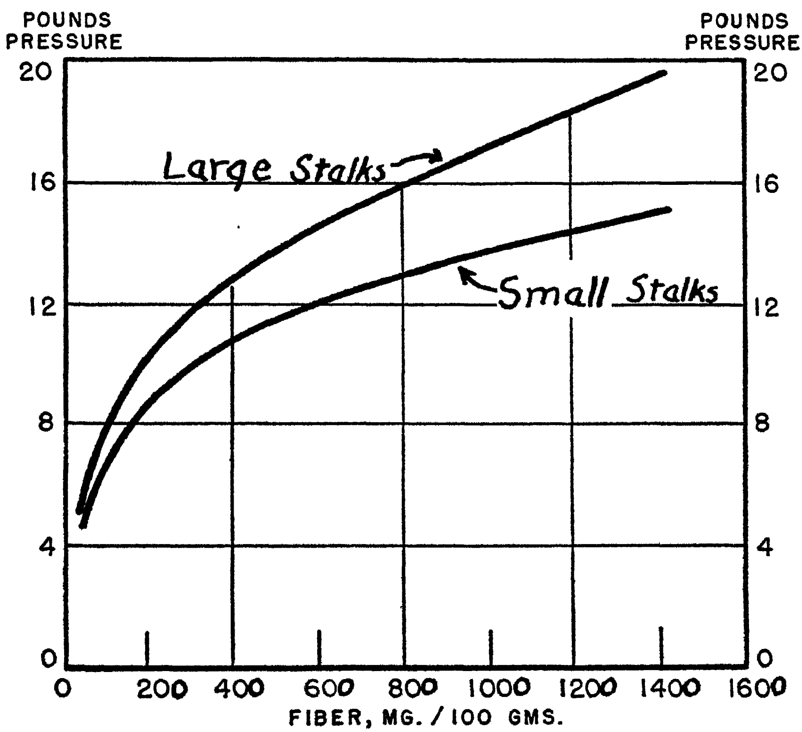


Fig. 8. Relation of fiber content to pressure readings on raw asparagus.

quality such as flavor of raw or processed asparagus are affected by the freshness of the product, except when freshness is lacking to the point that the stalks wilt. Even then, however, it is not known whether there is a deleterious effect in any respect except for the appearance of the fresh product.

Results presented by Scott *et al* (4) showing decreasing ascorbic acid content resulting from increasing duration and temperature of storage, indicate that ascorbic acid content may be a good measure of freshness in asparagus.

*Methods:*—Ascorbic acid determinations on the raw product were made by a rapid colorimetric method as described by Scott *et al* (4). No organoleptic estimations for flavor or other factors of quality that might be influenced by freshness, were attempted for the raw product, but the canned and frozen samples were scored organoleptically for flavor as indicated above.

*Discussion of Results:*—Although very large ascorbic acid losses were noted as a result of increasing temperature and especially duration of storage, organoleptic evaluations of the canned or frozen product showed no carryover effects of this loss of ascorbic acid in terms of flavor or any other observations. It may be assumed therefore, that the freshness of asparagus is reflected in the appearance of the raw uncooked product only, where its effect might be classified as a defect and may be described as an increasing proportion of wilted stalks and spreading tips. Since these correlations between ascorbic acid and flavor were not found to be significant, the data are not presented here. The ascorbic acid data are presented in detail elsewhere (4).

## Summary and Conclusions

Two hundred samples of raw, canned, and frozen asparagus were prepared in Maryland, New Jersey, and Delaware during the 1948 season, and analyzed for color, fibrousness, and freshness. The color method was based on the transmittance of light at 665 mμ of an acetone extract of asparagus pigment. The fibrousness of the raw product was measured by the use of two instruments where the pressure required for a blade .017 inch thick, to cut through one asparagus stalk, was recorded. Fibrousness of the raw and processed product was also measured by a rapid fiber determination involving the shredding of the sample in a Waring blendor and washing through a 30-mesh screen. Freshness was measured by determining the ascorbic acid content.

On the basis of the above data, "green" asparagus may be defined as asparagus containing not less than 10 parts per million of green pigment calculated as chlorophyll. This value was equivalent to 91 per cent transmittance when using the Beckman spectrophotometer, and 94 per cent transmittance when using the Leitz photoelectric colorimeter. These green pigment values were closely correlated with organoleptic evaluations of color; however, the accuracy of pigment values obtained on the raw product in predicting the color of the canned product was greatly reduced because storage of the raw product tended to decrease the pigment content of the raw stock, whereas fresh

and stored samples had similar color values after canning. Losses in color resulted from canning and freezing operations as well as from cooking of the frozen product.

Fiber content of fresh or processed asparagus was very closely correlated with organoleptic evaluation of fibrousness. Pressure readings of the raw asparagus were also closely correlated with organoleptic evaluations of the processed product, when separate scales were established on the basis of diameter of stalk. Higher pressure readings were obtained for the large stalks than for small stalks having the same fiber content and the same organoleptic values for fibrousness.

Although ascorbic acid content was closely correlated with freshness as indicated by duration and temperature of storage, these values could not be associated with the flavor, or any other characteristics of the cooked, canned, or frozen products. It thus appears that freshness is a factor affecting only raw asparagus and as such it may well be included under the item of defects and described in terms of greater percentage of wilted stalks or spreading tips.

## Literature Cited

1. Lee, F. A. Determination of toughness of frozen asparagus. *Food Res.* 8: 249–253. 1943.
2. ——— and Sayre, C. B. Tenderometer readings as an index of quality of fresh asparagus. A preliminary paper. *Food Res.* 5: 161–166. 1940.
3. MacGillivray, J. H. Seasonal variations in the tenderness of asparagus. *Proc. Amer. Soc. Hort. Sci.* 30: 558–560. 1933.
4. Scott, L. E., Kramer, A., and Guyer, R. B. Physiological changes in green asparagus after harvest. Manuscript to be submitted for publication.
5. Smith, H. R., and Kramer, A. The fiber content of canned green asparagus. *The Canner* 104: 18: 14–16. April 26, 1947.
6. U. S. Standards for Green Asparagus for Canning or Freezing. *Mimeo.* Reissued Feb. 3, 1948. Washington, D. C.
7. U. S. Standards for Grades of Canned Asparagus. Mimeo. Issued April 27, 1945. Washington, D. C.
8. Wilder, H. K. Instructions for use of the fiberometer in the measurement of fiber content in canned asparagus. *Res. Lab. Rep.* No. 12313–C. *Natl. Canners Assoc.* San Francisco. June 16, 1948.

# Moisture Losses of Vegetables Packaged in Transparent Films and Their Effect on Shelf-Life[1]

By Robert E. Hardenburg, *Cornell University, Ithaca, N. Y.*

One of the commonly claimed advantages for prepackaging vegetables is a longer shelf-life (3), because shrinkage is reduced by the use of moisture-proof or semi-moistureproof wrapping materials. Shrinkage losses of vegetables are almost entirely the result of the evaporation of water from the surface. Admittedly there is some loss of solids from respiration, and some loss from retrimming.

Platenius (4) showed under varied conditions that severe wilting occurs in almost all kinds of bulk fruits and vegetables if weight losses exceed 10 per cent. It has been pointed out (1, 2) that losses of less than 5 per cent in weight do not detract materially and are of little economic significance. The loss of water may amount to an appreciable weight loss particularly when vegetables are sold by the pound. In addition, it reduces the attractiveness of vegetables and lowers eating quality.

As part of a prepackaging study at Syracuse, New York during July and August 1947, moisture losses and the shelf-life of eight prepackaged vegetables were determined under two conditions, in open-top refrigerated Hussman cases (45 to 50 degrees F) and on open counters (80 to 90 degrees F).

## Materials and Methods

Produce and facilities were made available for the study through the cooperation of the Grange League Federation and the P. and C. Chain Stores at Syracuse, New York. Snap beans, broccoli, Pascal celery, lettuce, spinach, cauliflower, peppers and radishes, all New York grown, were purchased at the terminal market and packaged by hand the same morning at the chain store warehouse. Twelve different transparent films for testing were supplied by E. I. du Pont Company, Celanese Plastics Corporation, Goodyear Rubber Company, and Bakelite Corporation.

Treatments prior to packaging consisted of cutting cauliflower and broccoli into segments ready for cooking, and trimming radishes to leave only ½ inch of tops. Pascal celery, lettuce, spinach, radishes and broccoli were washed and dried.

Packaging consisted of placing the vegetables in transparent bags; except for lettuce which was overwrapped on a U-board and Pascal celery which was overwrapped in a paperboard tray. The packages were provided both with and without two ¼-inch ventilation holes so comparisons could be made.

The prepackaged vegetables, along with unwrapped checks, were

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[1]Paper No. 309, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

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delivered to a store where some were placed in a refrigerated case and others on an open counter. They were guarded by a sign marked "Experimental — Not for Sale". There were two to four replicate packages of each treatment. Each package was weighed to the nearest gram daily until it was judged non-salable without a markdown. A 10 to 1 rating system was used, 10 being excellent, 5 being just salable, 1 representing complete breakdown. The numbers in between represented other degrees of salability or non-salability. For example, if on the third day a package was rated 4 or non-salable without a markdown, then the shelf-life was recorded as 2 days for that package.

## Results and Discussion

Only the per cent weight loss at the shelf-life period is presented in this paper (Table I). Also, only data on three of the films are presented here: Lumarith (CA 100) a semi-moistureproof film, 300 MSAT cellophane, and 75P6A pliofilm, both of which are practically moisture-proof. Prepackaging, using either cellophane or pliofilm increased the shelf life of green beans, Pascal celery, head lettuce, and green peppers when retailed either on an open counter or in a Hussman refrigerated case. The shelf life of radishes was increased by topping and prepackaging in either of these films, when retailed in a refrigerated case. Lumarith as a wrapping material increased the shelf-life of Pascal celery, radishes and green peppers on an open counter, and green beans, Pascal celery, radishes and green peppers in a refrigerated case.

Cellophane and pliofilm were effective in keeping moisture losses below 5 per cent during the salable life of all eight vegetables, and below 2 per cent in most cases. Lumarith, a film giving maximum visibility, was not nearly as effective in reducing moisture losses. The addition of ventilation holes did not increase moisture loss significantly for any of the vegetables tested.

In that vegetables are selected quite largely by appearance, the prevention of shrinkage is important. Even though water loss may be largely prevented by these films, the shelf-life of some vegetables packaged within them may be no longer because of other forms of deterioration. Some of these are mentioned under the notes on specific vegetables.

*Green Beans:*—Bulk beans and beans packaged in Lumarith deteriorated because of moisture loss. Beans prepackaged in cellophane or pliofilm deteriorated as the result of moisture accumulation. In the latter two films, beans became water soaked, rubbery and would not snap on bending.

*Broccoli:*—Unwrapped broccoli had a shelf life of only 1 day on an open counter because of moisture loss and the opening of the yellow flowers. Although prepackaging reduced this moisture loss significantly at odds of greater than 99:1, the shelf life was still only 1 day because of yellowing. There was also a slight off odor on the open counter after 1 day, even when the bags were ventilated.

*Pascal Celery:*—The per cent weight loss shown for unpackaged

TABLE I—MOISTURE LOSS AND SHELF-LIFE OF VEGETABLES PACKAGED IN VARIOUS TRANSPARENT FILMS

| | Open Counter 80 to 90 Degrees F | | Refrigerated Case 45 to 50 Degrees F | |
|---|---|---|---|---|
| | Shelf-Life (Days)† | Per Cent Weight Loss at Shelf-Life* | Shelf-Life (Days)† | Per Cent Weight Loss at Shelf-Life* |
| | | *Green Beans* | | |
| Unwrapped | 4 | 21.4 ± 0.76 | 6 ± 0.00 | 17.1 ± 0.72 |
| Lumarith CA100 | 4 | 19.8 ± 1.10 | 7 ± 0.67 | 15.1 ± 1.24 |
| Cellophane 300 MSAT | 5 | 4.5 ± 0.15 | 9 ± 0.34 | 4.1 ± 0.40 |
| Pliofilm 75 P6A | 5 | 3.7 ± 0.12 | 9 ± 0.00 | 3.7 ± 0.42 |
| | | *Broccoli* | | |
| Unwrapped | 1 | 13.6 ± 0.14 | 1 ± 0.00 | 9.7 ± 0.55 |
| Lumarith CA100 | 1 | 6.9 ± 0.05 | 2 ± 0.00 | 8.1 ± 0.95 |
| Cellophane 300 MSAT | 1 | 0.5 ± 0.45 | 2 ± 0.00 | 0.9 ± 0.00 |
| Pliofilm 75 P6A | 1 | 0.2 ± 0.20 | 2 ± 0.00 | 0.9 ± 0.00 |
| | | *Pascal Celery* | | |
| Unwrapped | 2 | 11.5 ± 0.44 | 4 ± 0.58 | 16.5 ± 2.99 |
| Lumarith CA100 | 5 | 17.9 ± 0.60 | 6 ± 0.58 | 12.0 ± 2.77 |
| Cellophane 300 MSAT | 5 | 2.8 ± 0.06 | 7 ± 0.63 | 2.1 ± 2.78 |
| Pliofilm 75 P6A | 4 | 1.9 ± 0.03 | 7 ± 0.26 | 2.1 ± 0.48 |
| | | *Cauliflower* | | |
| Unwrapped (Head) | 3 | 6.7 ± 0.10 | — | — |
| Lumarith CA100 | 1 | 2.0 ± 0.00 | 3 ± 0.00 | 5.9 ± 0.25 |
| Cellophane 300 MSAT | 1 | 0.4 ± 0.15 | 2 ± 0.50 | 0.2 ± 0.15 |
| Pliofilm 75 P6A | 1 | 0.2 ± 0.15 | 1 ± 0.50 | 1.0 ± 0.00 |
| | | *Lettuce (Head)* | | |
| Unwrapped | 2 | 20.5 ± 3.45 | 3 ± 0.50 | 22.4 ± 2.35 |
| Lumarith CA100 | 2 | 8.4 ± 0.25 | 3 ± 0.50 | 8.3 ± 0.20 |
| Cellophane 300 MSAT | 4 | 0.8 ± 0.05 | 7 ± 0.50 | 1.3 ± 0.40 |
| Pliofilm 75 P6A | 4 | 1.4 ± 0.10 | 7 ± 1.00 | 1.7 ± 0.35 |
| | | *Spinach* | | |
| Unwrapped | 1 | 11.3 ± 0.35 | — | — |
| Lumarith CA100 | 1 | 7.6 ± 0.30 | 1 ± 0.00 | 5.5 ± 0.10 |
| Cellophane 300 MSAT | 1 | 0.3 ± 0.00 | 2 ± 0.50 | 0.5 ± 0.20 |
| Pliofilm 75 P6A | 1 | 0.5 ± 0.20 | 2 ± 0.00 | 0.5 ± 0.20 |
| | | *Radishes* | | |
| Unwrapped (bunch) | 1 | 22.9 ± 0.24 | 2 ± 0.00 | 30.7 ± 2.40 |
| Lumarith CA100 | 2 | 8.3 ± 0.14 | 5 ± 0.00 | 13.3 ± 0.90 |
| Cellophane 300 MSAT | 1 | 0.4 ± 0.00 | 4 ± 0.50 | 1.3 ± 0.40 |
| Pliofilm 75 P6A | 1 | 0.6 ± 0.20 | 4 ± 0.00 | 0.4 ± 0.00 |
| | | *Peppers* | | |
| Unwrapped | 4 | 8.1 ± 0.61 | 16 ± 1.33 | 4.3 ± 0.35 |
| Lumarith CA100 | 6 | 8.1 ± 0.59 | 24 ± 1.67 | 4.2 ± 0.52 |
| Cellophane 300 MSAT | 6 | 1.3 ± 0.10 | 28 ± 1.00 | 0.8 ± 0.12 |
| Pliofilm 75 P6A | 6 | 1.5 ± 0.21 | 26 ± 2.43 | 0.3 ± 0.00 |

*Per cent weight loss refers to weight loss at the shelf-life period as shown in the shelf-life column. This weight loss is not for any standard number of days. It varies between kinds of vegetables and between treatments. For example green beans in Lumarith lost 19.8 per cent in weight during their shelf-life of 4 says, while beans in cellophane lost 4.5 per cent during their shelf-life of 5 days. Also shown is the standard error of the mean.

†The standard error of the mean for these shelf-life periods was zero for those treatments on the open counter. In the refrigerated case, the standard error of the mean for each shelf-life period is shown in the table.

celery includes trimming the browning from the butt to keep it dressed up as a store produce man would do. On an open counter, the shelf life of celery in Lumarith was limited by drying and browning of the leaves. Packaged in cellophane or pliofilm it was limited by yellowing of the leaves and the development of slime and a cooked celery odor after 7 days.

It was interesting to note that in a refrigerated case a second layer of packages of celery had approximately twice the shrinkage of the lower layer of packages.

*Cauliflower:*—The comparison here is between whole heads of cauliflower unwrapped, and packages containing cauliflower cut up into segments. Although shrinkage was largely prevented by packaging, other factors in the form of slime and blackening of the cut surfaces caused the short shelf-life, both refrigerated and unrefrigerated.

*Lettuce:*—The 20.5 per cent loss in weight of the bulk lettuce in 2 days includes trimming it up at the beginning of the second day. The moisture-proof films, cellophane and pliofilm, doubled the possible salable period both on open counters and in a refrigerated case. However, beyond 4 days on an open counter and 6 to 7 days in a refrigerated case, the moisture saturated atmosphere favored the development of rot and slime organisms.

*Spinach:*—Moisture loss was not the main cause of spinach deterioration during hot weather, so prepackaging was not beneficial, when the product was marketed un-refrigerated. Spinach breakdown was more rapid in the moistureproof films than in bulk. Lumarith packaged spinach became dry on top yet slimy beneath, when held for more than 1 day under either temperature condition. Ventilation holes to prevent off odors were found to be essential for the moistureproof films, cellophane and pliofilm.

*Radishes:*—This comparison is between bunched radishes with tops and packaged radishes having most of the tops removed. The use of Lumarith bags extended the shelf life over that of unwrapped radishes. However, the packaged radishes became unsalable in 2 to 5 days depending on the temperature because of excess moisture loss and darkening of the surface. The two moistureproof films maintained the radishes in a turgid condition, but the shelf-life was not lengthened on an open counter. The short tops began to rot; the radishes became slimy, and putrid odors developed. The high humidity within these films also favored sprouting. Carolus (1) had indicated that naphthalene acetic acid will inhibit sprout growth of prepackaged root crops.

Ventilation was essential to help reduce the troubles arising from sub-oxidation. One fault of ventilation holes, particularly with radishes, was that they provided an entrance for small fruit flies when retailing was on an open counter.

*Green Peppers:*—Peppers shrivelled by moisture loss are a common sight on produce counters. Prepackaging increased the shelf-life by reducing water loss, but the shelf-life was eventually limited on the open counter by ripening, turning orange, and by mold formation in the stem scars. Under conditions in the refrigerated case, it was limited by the development of mold and soft rots.

## Summary

300-MSAT cellophane and 75-gauge pliofilm were effective transparent films for lengthening shelf-life and reducing moisture loss with several vegetables. However, with certain other vegetables, Lumarith

(cellulose acetate 100) was as good or better; especially where evaporation of water was not the main cause of deterioration or with products where a very high humidity caused rapid mold formation.

## Literature Cited

1. Carolus, R. L. Quality factors of prepackaged fresh produce. *Pre-Pack-Age.* October 1947.
2. Comin, D., and Junnila, W. Water loss from vegetables in storage. *Ohio Bimonthly Bul.* 243. November-December 1946.
3. Hauck, C. W. Shelf life of fresh fruits and vegetables can be lengthened. *Ohio Bimonthly Bul.* 241. July-August 1946.
4. Platenius, Hans. Films for produce...their physical characteristics and requirements. *Modern Packaging.* October 1946.

# The Initiation of Natural Breaks in Azalea[1]

By B. Esther Struckmeyer and R. H. Roberts, *University of Wisconsin, Madison, Wis.*

The production of plants of azalea in the greenhouse includes the operation of pinching which is expensive and occasionally not too successful. Branches of azalea plants var. Coral Bell grown during the

Fig. 1. Axillary buds of shoots that are disbudded before the open flower stage start to break. Left, size of breaks 5 weeks after disbudding. Center and right, axillary buds present, but will not break until flower has dried and dropped.

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winter season are pinched or sheared to increase the number of shoots and to produce well branched, compact plants. When plants are sheared some shoots are sometimes too short to produce vigorous breaks from the axillary buds near the cut ends. A short shoot does not produce a satisfactory growth of the breaks just above a crotch. However, outside shoots produce good growth from the breaks. As a result plants frequently grow with a hollow center. It is recommended that when the pinching method is used, all shoots should be left between 2 and 3 inches long.

The question arose some seasons ago as to the possibility of finding a method which would induce breaks and eliminate the operation of pinching. It is the habit of azalea shoots to produce breaks after the plant has flowered. At this stage the flowers were dry and some were falling from the plant. Fig. 1 shows that flowering delayed the breaking of the axillary buds.

With some environmental conditions terminal bud abortion occurs accompanied by the production of breaks. Can this growth habit be controlled and used in the forcing of natural breaks? Experimental trials in the University greenhouses and in a commercial greenhouse indicated that this can be accomplished. Breaks were induced on approximately 50 plants at the University greenhouses and between 35,000 and 40,000 plants in a commercial greenhouse[2] during the winters of 1946–47 and 1947–48 by varying the temperature. Varieties other than Coral Bell growing in the same greenhouse made breaks at the same time under this treatment.

FIG. 2. Left, plant kept continuously cool for 11 weeks. Right, plant kept at cool temperature for 5 weeks and then transferred to warm temperature for 6 weeks. The breaks have made sufficient growth to be returned to the cool temperature for the development of a second set of axillary buds.

[2]Holton & Hunkel, Milwaukee, Wisconsin.

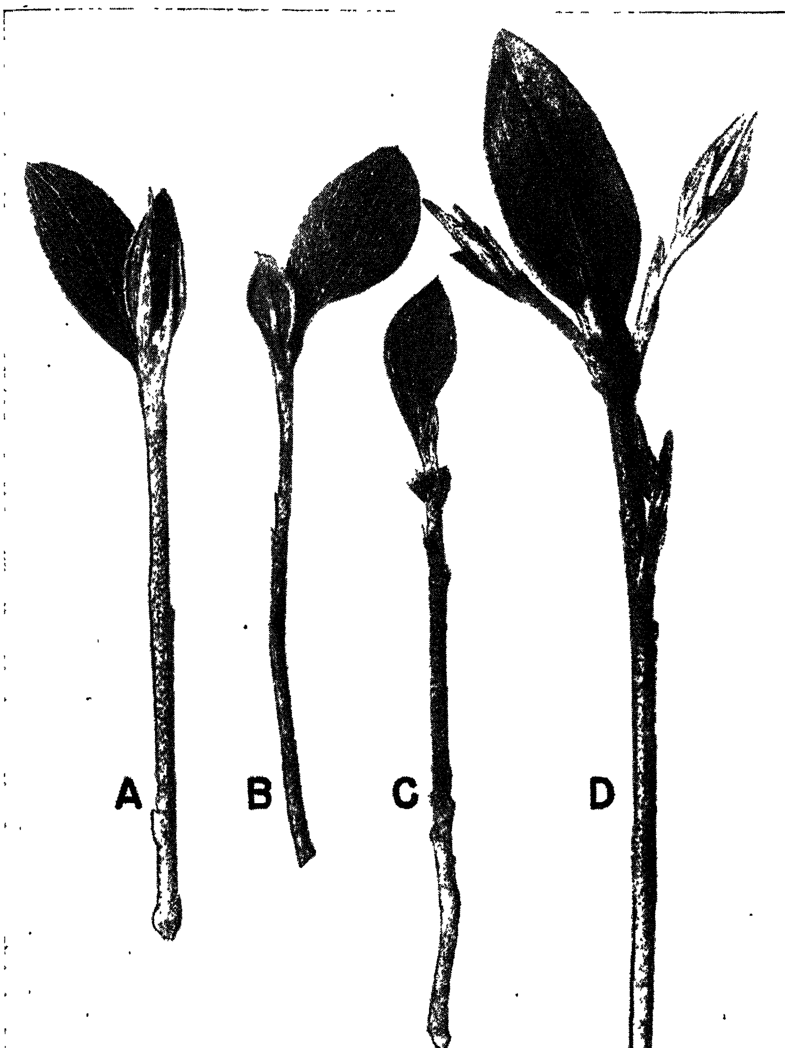


FIG. 3. Detail of axillary buds and breaks. A, vegetative shoot. B, growth made from terminal apex, continued vegetative. C, plant given sufficient cooling to have large enough axillary buds to break when transferred to warm temperature. D, breaks from shoot that has had a warm temperature after cool period.

Plants of azalea from spring cuttings carried at temperatures of 50 degrees F during late November and December for about 5 weeks formed axillary buds. When these plants were then exposed to a minimum temperature of 60 to 65 degrees F numerous breaks were pro-

duced as shown in Fig. 2. The axillary buds were inhibited on plants that were kept at the cool temperature considerably longer than 5 weeks. In this case the axillary buds did not break until after the shoot had flowered.

Breaks occurred from buds in the axils of the leaves surrounding the terminal bud as recorded in Fig. 3. The stage at which plants were transferred from a cool temperature to a warm temperature depended on the size of the axillary bud. Large axillary buds were most commonly associated with large leaves.

Numbers from 1 to 9 were arbitrarily given to axillary buds of different sizes ranging from small to large. Buds of sizes 1 to 3 failed

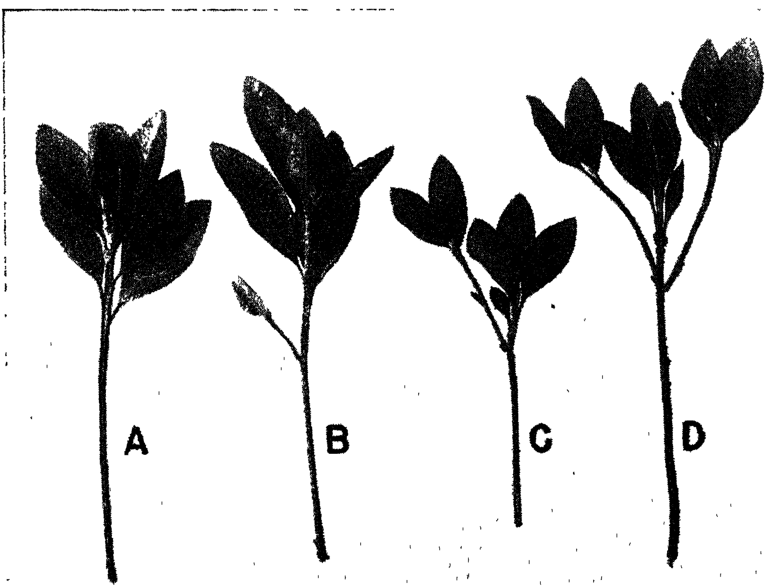


FIG. 4. Relation of size of axillary bud to breaking at warm temperature. A, axillary bud of size 3, too small to break. B, axillary bud of size 4 developed a weak break. C, axillary bud of size 5 developed a stronger break. D, axillary buds of size 6 developed two strong breaks.

to break when transferred to a warm temperature; at sizes 4 and 5 about half were sufficiently well developed to break; and all buds of size 6 and larger produced breaks. Measurements of axillary bud width in millimeters gave the following averages: size 3, .68; size 5, 1.07; size 7, 1.96; and size 9, 2.73. Axillary buds made breaks when the width of the axillary bud was at least half the width of the stem which supported it. Figs. 4 and 5 show the relation of size of axillary bud formed in the cool temperature to the production of breaks at a high temperature.

It appears possible to produce a second set of axillary buds for

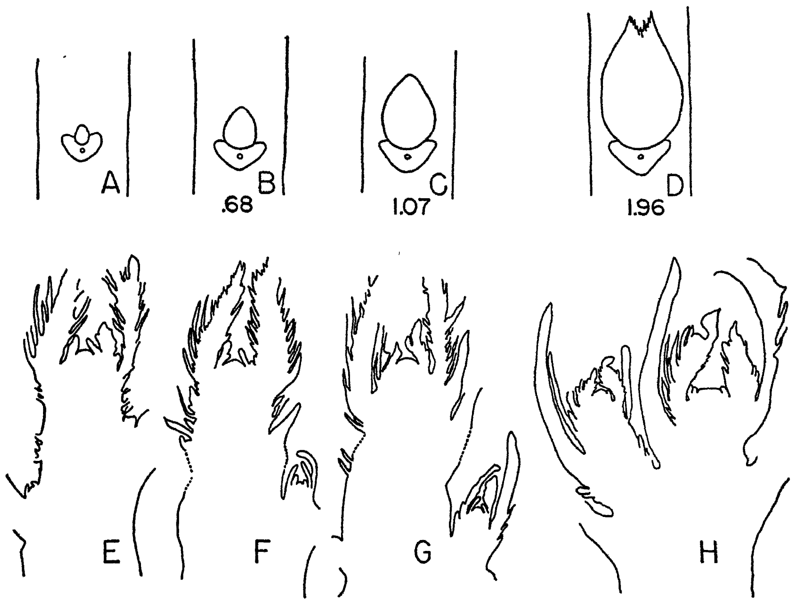


FIG. 5. Diagram of sizes of axillary buds (A–D) and width in millimeters. Sizes above 5 (C,G) break readily. Camera lucida drawings of terminal and axillary buds (E–H). Stages from small axillary buds on vegetative shoot (E) to axillary buds that will break (G and H).

breaking during the winter growing season in Wisconsin, the first beginning November 10 to 15 and the second between February 1 to 15. After this latter period the warmer outdoor temperatures may interrupt the maintenance of greenhouse temperatures sufficiently cool to develop the terminal and the accompanying axillary buds. Approximately 5 weeks of a warm temperature are needed to produce sufficient growth from the first set of breaks before they in turn can be chilled to produce the second set. As 5 to 6 weeks are needed to produce axillary buds of a size that will break and a comparable length of time to secure breaks sufficiently long to produce another set of terminal and axillary buds, a total of 15 to 18 weeks is needed to chill, break, and again chill in preparation for the second break at a warm temperature. It is possible to do this between November 10 to 15, when cool weather arrives in Wisconsin, and March 15 to 20.

Advantages of inducing breaks without pinching are the reduction in amount of fuel used during the chilling period as well as the amount of labor for pinching. Also cuttings that are taken from plants that have axillary buds ready to break give a more desirable plant than those that are pinched as is shown by Fig. 6.

FIG. 6. The development of a plant from a cutting which had axillary buds sufficiently large to break when the cutting was made.

## SUMMARY

Azalea plants can be conditioned for breaking by growing them in a cool temperature of 50 degrees F for 5 to 6 weeks during November and December. In this period the axillary buds become sufficiently large to produce breaks when a warmer growing temperature is provided.

# Spring Flowering Chrysanthemums

By D. C. KIPLINGER and RAYMOND HASEK, *Ohio Agricultural Experiment Station, Wooster, Ohio*

FROM the original work by Garner and Allard (1), practical applications of photoperiodism on many crops have been made by Laurie (2), Poesch (3), and Post (4). However, there have been numerous investigations with the chrysanthemum because of its quick response to shading and additional light.

The early work on shading resulted in the rapid use of this technique by commercial growers to obtain earlier flowering. The initial tests with additional light were disappointing in that the quality of the product was inferior. This was due undoubtedly to the attempts made to flower the chrysanthemum in winter when growing conditions were poor. Because of the favorable weather conditions in April, May, and June it appeared that this season offered greater promise for the flowering of the chrysanthemum. Stuart (5) has reported on the success of flowering the chrysanthemum during the spring months. Preliminary tests at the Ohio Agricultural Experiment Station were conducted in 1944 and 1945.

## RESULTS IN 1946

Rooted cuttings of a number of pompon chrysanthemum varieties were benched January 2, 1946, at a distance of 7 by 8 inches. To prevent formation of flower buds, 10 foot-candles of light were supplied for 2 hours each night, from 6 pm to 8 pm, and the cuttings had been given this quantity of light while in the propagation bench. The lights were on from January 2 to March 1 on one bench and from January 2 to March 13 on another bench. Black shading cloth was applied each night from 5 pm to 7:30 am after the lights were discontinued. Prior to the use of black cloth the night temperature was maintained at 50 degrees F, but on March 1, the night temperature was raised to 60 degrees F to insure flower bud formation. The plants were pinched January 25 and pruned to two stems.

On the bench shaded March 1, the average date of maturity was May 1, and on the bench shaded March 13, the average date of maturity was May 10. Observation of the plants showed that some varieties were superior to other for spring flowering. The varieties that were best from the standpoint of production and quality were Arcadia and Yellow Arcadia, Carolyn Yosick, Graceland, Linda Lou, Pinocchio, Shasta, and White Mensa. Some varieties formed flower buds under the 2 hour period of additional light which indicated that this period of lighting was insufficient.

## RESULTS IN 1947

Rooted cuttings of a number of pompon chrysanthemums were benched December 1, 1946, at a distance of 8 by 8 inches. The plants were pinched December 27, 1946, and pruned to three stems. Ten

foot-candles of light were supplied from 6:00 pm to 11:00 pm each night. The night temperature was maintained at 60 degrees F until the lights were discontinued on February 6, 1947, at which time the night temperature was raised to 65 degrees F. When flower buds were visible on February 18, 1947, the night temperature was reduced to 60 degrees F. The average date of maturity was April 10, 1947.

Another bench was planted December 12, 1946, and lighted until March 1. The manipulation of night temperature and the use of lights were the same as described above. The plants were pinched February 10, 1947, and pruned to three stems. No black cloth was applied after lighting was discontinued on March 1, and the average date of maturity was May 13.

The varieties that were best from the standpoint of production and quality in addition to those listed for 1946 were Barcarole, Blanche, Brocade, Constellation, Gold Coast, Golden Herald, Sea Gull, and Soprano.

## Results in 1948

Several disbud types of chrysanthemums were grown because of their novelty at this season of the year. Rooted cuttings of Golden Herald, Little America, Masterpiece and Bronze Masterpiece were benched December 2, 1947, at a distance of 8 by 8 inches. The plants were pinched January 3, 1948, pruned to two stems, and then pinched again February 4, 1948, pruned to three stems per stem, making six stems per plant. Ten foot-candles of light were supplied each night from 6:00 pm to 11:00 pm from benching until March 1, 1948, and no shade was applied to set flower buds as the previous year's test indicated it was not necessary at this date. The night temperature was 60 degrees F until March 1, 1948, then raised to 65 degrees F until flower buds were visible, and then lowered to 60 degrees F until maturity on May 1.

All of the varieties tested were found to be suitable for spring flowering.

## Observations and Conclusions

The flowering season of the chrysanthemum may be extended to the spring months by the manipulation of light and temperature.

There are several important requisites which must be observed if the method is to be successful.

1. Cuttings must be taken from lighted stock plants.
2. To prevent flower bud formation the light intensity should be 10 foot-candles and the duration of lighting should be at least 4 hours each night.
3. For best results the night temperature should be maintained at 60 degrees F at all times except when flower buds are being initiated and then a 65 degrees F night temperature is preferred.
4. No black shading cloth is necessary for setting flower buds if the lighting is discontinued prior to March 1 in the latitude of Central Ohio.

To secure the best production and quality the following schedule of operations is suggested:

SCHEDULE OF OPERATIONS—SPRING FLOWERING OF CHRYSANTHEMUMS

| Desired Flowering Date | Bench Rooted Cuttings On | Begin Lighting | Pinch | Discontinue Lighting | Shade Beginning |
|---|---|---|---|---|---|
| Apr 1 | Nov 15 | Nov 15 | Dec 5 | Jan 15 | Not necessary |
| May 1 | Dec 20 | Dec 20 | Jan 10 | Feb 25 | Not necessary |
| Jun 1 | Feb 1 | Feb 1 | Feb 20 | Mar 28 | Mar 28 |

For a spring flowering crop it appears that no varieties should be used which normally mature later than November 20, as they require too long a period to come into flower. Not all of the earlier varieties are suitable for spring flowering. Some of the better types of pompons are Arcadia, Barcarole, Blanche, Brocade, Carolyn Yosick, Constellation, Gold Coast, Golden Herald, Graceland, Linda Lou, Pinocchio, Sea Gull, Shasta, Soprano, Yellow Arcadia, and White Mensa. For disbuds Bronze Masterpiece, Golden Herald, Little America, and Masterpiece are suitable.

## LITERATURE CITED


1. GARNER, W. W., and ALLARD, H. A. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. *Jour. Agr. Res.* 18: 533–606. 1920.
2. LAURIE, ALEX. Photoperiodism, practical application to greenhouse culture. *Proc. Amer. Soc. Hort. Sci.* 27: 319–322. 1930.
3. POESCH, G. H. Prolonging the flowering period of chrysanthemums with the use of supplementary illumination. *Proc. Amer. Soc. Hort. Sci.* 34: 624–626. 1936.
4. POST, KENNETH. Effect of day length and temperature on growth and flowering of some florist crops. *N. Y. (Cornell) Agr. Exp. Sta. Bul.* 787: 1–70. 1942.
5. STUART, NEIL W. Growing chrysanthemums in subirrigated vermiculite for spring bloom. *Proc. Amer. Soc. Hort. Sci.* 51: 593–595. 1948.

# Effects of Ethylene on Orchid Flowers[1]

By O. W. DAVIDSON, *Rutgers University, New Brunswick, N. J.*

ORCHID growers in various parts of the country have, from time to time, reported injury to the sepals of their flowers. It has been observed that the injury begins while the flowers are in the advanced bud stage, with sepals just beginning to split apart. Mature flowers on the same or adjoining plants appear not to be affected when injury develops on a high percentage of the opening buds. This injury has occurred periodically and almost exclusively during the fall and early winter months, and has been associated with calm, humid, cloudy weather when barometric pressure is somewhat below normal. During November 21 and 22, 1947, for example, such conditions prevailed and were associated with the development of considerable "dried-sepal injury" in various greenhouses located within a radius of 50 miles of New York.

This injury to orchid flowers is characterized by a progressive drying and bleaching of the sepals, beginning at the tips and extending toward the bases. Abnormalities in the sepals become apparent as the blooms reach maturity. In severe cases the affected sepals are readily distinguished, whereas in mild cases fresh blooms might appear normal to most observers. Nevertheless, the keeping quality of blooms affected by dried-sepal injury is drastically impaired.

One of the earliest indications of dried sepals is a slight depression in the tissues between the veins near the tips of the sepals. This collapse and drying of tissues between the veins progresses with time and is accelerated by warm temperatures. Typical symptoms of this injury are illustrated in Figs. 1 and 2.

In some greenhouses, in addition to the sepal injury that occurred as an apparent result of atmospheric conditions on November 21 and 22, 1947, many flowers of some hybrids failed to open normally, if at all. The flowers and opening buds of some Brassocattleya hybrids in particular were severely deformed. From these observations it was assumed that the factor causing dried sepals might, under some circumstances, affect petals also.

Two incidents lead to the initiation of the following series of experiments. On December 9, 1947 and again on January 29, 1948, *Cattleya Trianae* plants allowed to stand overnight in a laboratory in the Horticulture Building of the New Jersey Agricultural Experiment Station developed typical dried-sepal injury. A slight odor of illuminating gas could be detected in this laboratory when first opened for the day. On January 28, 1948 Wallace R. Pierson, Jr. telephoned from Cromwell, Connecticut to report that the fumes from a small gasoline-

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[1]Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Horticulture.

The author wishes to acknowledge the valued assistance given him during this investigation by Thomas Young Orchids, Inc., Bound Brook, N. J., by Wallace R. Pierson, Jr., Cromwell, Conn., and by Abraham Marmon, Flushing, N. Y. Particular gratitude is extended to Leslie Erickson of Thomas Young Orchids, Inc. for the fine cooperation and help given by him.

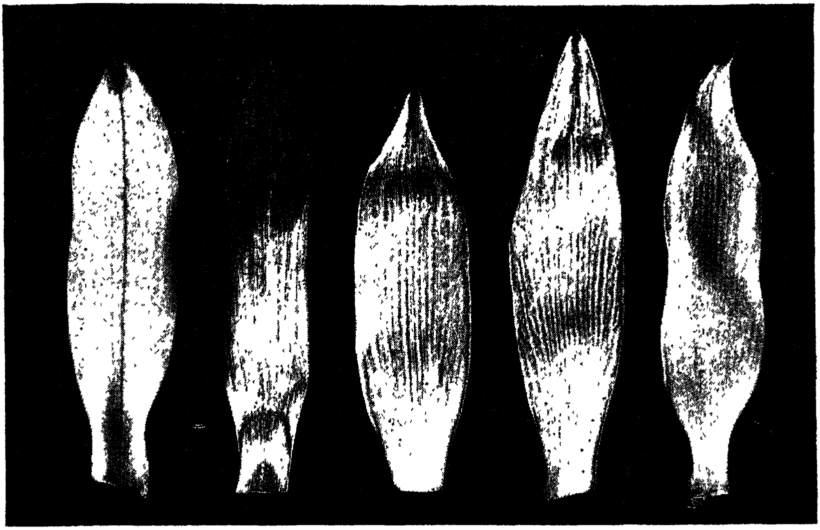

FIG. 1. Effects of ethylene on sepals of *Cattleya Mossiae,* as indicated by necrosis and by shrinkage of tissues particularly between the veins. Left to right: control, 0.1 ppm ethylene for 16 hours, 0.04 ppm for 8 hours, 0.04 ppm for 24 hours, and 0.01 ppm for 48 hours.

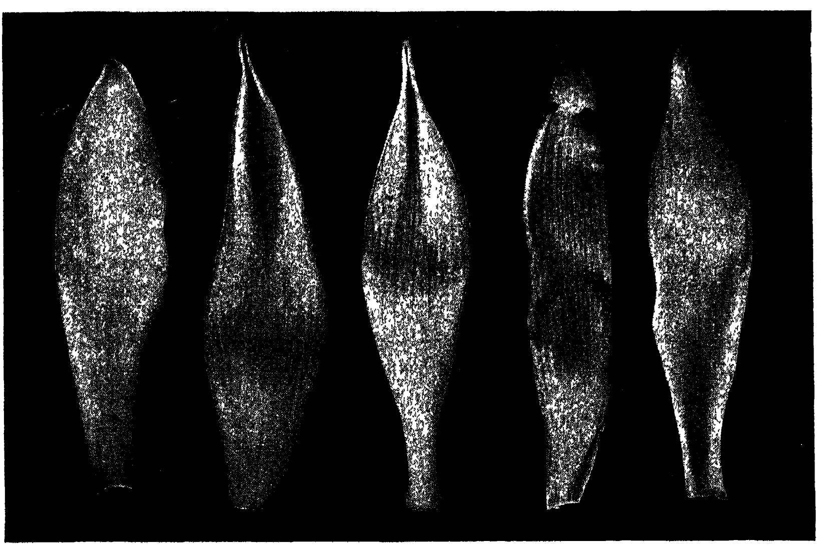

FIG. 2. Effects of ethylene on sepals of *Cattleya Trianae.* Left to right: control, 0.1 ppm ethylene for 16 hours, 0.04 ppm for 8 hours, 0.04 ppm for 24 hours, and 0.01 ppm for 48 hours.

powered concrete mixer used in an orchid house had apparently caused extensive injury to sepals and had also prevented some blossoms from opening normally.

On the basis of these observations, it was assumed that ethylene gas might be responsible for the development of dried-sepal injury. Accordingly, the following experiments were designed to test this assumption.

## Methods

Inasmuch as *Cattleya Trianae* flowers were known to be susceptible to dried-sepal injury, one or two plants of this species, together with one or two *C. Mossiae* or Cattleya hybrids, were exposed in each of several air-tight chambers used for a given series of treatments. All plants used were well-established, of good vigor, and carefully selected for each experiment. All contained from one to five buds that were just beginning to open, as indicated by the sepals splitting apart from each other. The relative stage of development and condition of each bud were noted.

Potted tomato plants 10 to 14 inches in height were placed in the chambers along with the orchid plants in three series of experiments. This was done to compare the relative sensitivity of opening orchid blooms and tomato plants to ethylene.

Air-tight chambers consisting of 30- and 55-gallon steel drums with removable tops (Quick-Lox) fitted with rubber gaskets, and a 16-gallon autoclave were used to expose the orchid plants to various concentrations of ethylene. The chambers were equipped with valves through which ethylene was introduced.

After the plants had been placed in the chambers, the latter were evacuated below atmospheric pressure by approximately 0.5 inch of mercury. Following this, measured amounts of C. P. ethylene were introduced into the chambers. The latter were then allowed to attain atmospheric pressure before the valves were closed to confine the gas mixtures.

In order to measure the very small amounts of ethylene required for these experiments, a micro-burette from a Van Slyke amino-nitrogen apparatus was used. Dilutions consisting of 1 part ethylene in 99 parts air, and 1 part ethylene in 999 parts air were prepared. From these 1: 100 and 1: 1000 stocks the amounts of ethylene required to give the desired concentrations in the chambers also were measured in the micro-burette. The tubing used for preparing the stock dilutions of ethylene was not used to deliver the gas to the chambers. After delivering a measured amount of gas to a chamber, the tubing used was aerated thoroughly before it was used again.

The chambers were located in a greenhouse compartment the temperature of which was controlled manually, and, when possible, was maintained at 68 to 70 degrees F at night and 75 to 80 degrees F during the day.

After the plants were exposed to ethylene for the desired length of time, they were removed from the chambers and placed in an orchid greenhouse for 2 to 6 days for observation. In all experiments the control plants were placed in chambers which were evacuated and then

given atmospheric pressure without the addition of ethylene. These plants, moreover, were kept in their chambers until the longest gas treatment in the given experiment was terminated. Following their removal from the chambers, the control plants were placed in the greenhouse along with the treated ones for observation.

After some preliminary exposures, made to determine the appropriate range of ethylene concentrations in which to work, a total of seven series of experiments was run. The concentrations of ethylene used varied from a maximum of 10 ppm to a minimum of 0.001 ppm. The minimum time of exposure studied was 8 hours and the maximum 48 hours.

## Results

*Response to Concentrations Exceeding 0.1 PPM:*—Opening flower buds of orchids exposed to ethylene in concentrations exceeding 0.1 ppm for periods longer than 8 hours, at the temperatures used in this study, were injured severely by the gas. The injury resulting to sepals and petals was more intense than that which usually occurs in orchid greenhouses. Flowers which were almost fully opened when exposed to 10 ppm ethylene, for example, failed to mature normally and collapsed within a few days, while their pedicels and those of opening buds developed an abnormal yellow tinge in response to this concentration of the gas.

Half-open blooms withstood 1 ppm ethylene for 20 hours, but had their development arrested by exposure to 5 ppm for the same time. Flower buds with sepals just beginning to split apart when exposed to 0.5 ppm or to 1 ppm ethylene for 20 hours remained closed and their tissues began to collapse in 3 or 4 days.

*Response to Concentrations of 0.1 PPM and Less:*—A 0.1 ppm concentration of ethylene in the atmosphere around orchid plants for a period of 8 hours produced typical and extensive dried-sepal injury to *Cattleya Trianae,* to some *C. Trianae* hybrids, and to *C. Mossiae* (Figs. 2 and 3). Exposure to 0.1 ppm ethylene for more than 8 hours usually produced severe injury to petals and prevented blossoms from opening normally (Fig. 3).

A 0.04 ppm concentration of ethylene for 8 hours produced typical symptoms of dried-sepal injury, such as occurs from time to time in greenhouses (Figs. 1 and 2). Even in this low concentration, some blossoms of *Cattleya Trianae* and *C. Mossiae* failed to open normally and collapsed in the greenhouse 4 or 5 days after removal from the chambers. Exposure to 0.04 ppm ethylene for 16 hours or more usually caused severe injury (Figs. 1 and 2), and prevented a majority of buds from opening normally.

A 0.02 ppm concentration of ethylene for 24 hours caused *Cattleya Trianae* and *C. Mossiae* to develop typical sepal injury within 2 days. This concentration, moreover, had a prominent retarding influence on the development of opening buds as compared with similar buds in the control treatment.

A 0.01 ppm concentration of ethylene for 12 to 24 hours caused slight but definite injury to *Cattleya Trianae* and *C. Mossiae* sepals

FIG. 3. Retarded and arrested development of *Cattleya Trianae* blooms in response to exposure to ethylene. Left to right: control, 0.1 ppm for 24 hours, 0.5 ppm for 24 hours.

within 2 days (Figs. 1 and 2). Except on close inspection, however, these flowers might have appeared normal when fully grown. Nevertheless, when they were allowed to remain on the plants for 3 or 4 days in the greenhouse, injury to the sepals became prominent. Moreover, when the flowers exposed to 0.01 ppm ethylene were cut from the plants and kept in a room, injury to the sepals usually became noticeable within a few hours.

A 0.005 ppm concentration of ethylene for 24 hours caused the development of slight but definite injury to the opening blossoms of *Cattleya Trianae* and to some *C. Trianae* hybrids within 2 days. Some buds, in which the sepals were just beginning to split apart when the plants were placed in the chambers, were retarded in opening.

A 0.002 ppm concentration of ethylene for 24 hours produced injury to the opening blossoms of *Cattleya Trianae* which became apparent only after the plants had been returned to the greenhouse and the flowers allowed to develop for 3 to 4 days. The injury caused by this concentration of the gas might easily have been considered insignificant when the flowers first opened. Nevertheless, considerable importance is associated with this degree of dried-sepal injury, for orchids are long-lasting flowers. An abnormality which might be noticed in the greenhouse but which would result in dissatisfaction to the buyer is very significant.

A 0.001 ppm concentration of ethylene for 24 hours failed to injure any flowers used in this treatment.

*Tests with Ethylene from an Apple:*—Two *Cattleya Trianae* plants, and a hybrid that was relatively resistant to ethylene, were placed in a 55-gallon drum containing one ripe and slightly shrivelled Cortland

apple weighing approximately 150 grams. The orchids were exposed to the emanations from the apple for 24 hours. All opening blossoms showed injury within a day after removal from the chamber. Thereafter the blossoms failed to open normally, and began to collapse after 4 days in the greenhouse. On the basis of the amounts of ethylene emanated from apples, as determined by Denny and Miller (1) and by Hansen (2), it is estimated that the orchids in this treatment probably were exposed to between 0.1 and 3 ppm ethylene during the 24-hour period, at a temperature of 68 to 80 degrees F. It should be emphasized that the apple probably generated ethylene during the entire exposure period and that, because of this fact, the maximum concentration of the gas was not attained until just prior to terminating the treatment.

*Control Plants:*—All control plants used in these experiments developed normal flowers. When removed from the chambers and kept in the greenhouse the buds and flowers on these plants showed no symptoms of dried-sepal injury.

*Tomato Plants:*—Tomato plants exposed with the orchids to ethylene in concentrations of 0.1 ppm for 8 and 16 hours, to 0.04 ppm for 8 hours, to 0.01 ppm for 12 hours, and to 0.005 ppm for 24 hours showed no epinastic response. In all of these treatments orchid blossoms were injured.

## Discussion

The response of opening orchid buds to ethylene probably ranks them highest among plant materials reported to date in sensitivity to this gas. Wallace (3) reported that apple cuttings, under suitable environmental conditions, will produce intumescences in response to exposure to 0.01 ppm ethylene for 48 to 72 hours; Denny and Miller (1) reported epinasty in young potato plants exposed to 0.05 ppm ethylene for 16 to 20 hours. The reason for the high degree of sensitivity of opening orchid buds to ethylene, together with the mode of action of the gas on the sepals, remains to be explained.

Although it has not been established by this investigation that the dried-sepal injury which develops in orchid greenhouses is caused by ethylene in the atmosphere, nevertheless it has been demonstrated that this gas in extremely dilute concentrations is capable of producing symptoms in the flowers that appear identical with this injury. Until ethylene is detected in toxic concentrations in the atmosphere of orchid greenhouses, we have only circumstantial evidence to indicate that this periodic and seasonal injury is caused by ethylene.

## Summary

Cattleya flower buds that are starting to open, as indicated by the sepals beginning to split apart from each other, are sensitive to extremely dilute concentrations of ethylene. The sepals of flowers in this stage of development are injured in a characteristic manner by exposure to as little as 0.002 ppm ethylene for 24 hours, or 0.1 ppm for 8 hours.

### Literature Cited

1. Denny, F. E., and Miller, L. F. Production of ethylene by plant tissues as indicated by epinastic response of leaves. *Contrib. Boyce Thomp. Inst.* 7: 97–102. 1935.
2. Hansen, Elmer. Quantitative study of ethylene production in apple varieties. *Plant Phys.* 20: 631–635. 1945.
3. Wallace, R. H. The production of intumescences in Transparent apple twigs by ethylene gas as affected by external and internal conditions. *Bul. Torrey Bot. Club* 54: 499–542. 1927.

# Factors Influencing Flower Production and Bud-Drop in Gardenias

By J. R. Kamp, *University of Illinois, Urbana, Ill.*

Bud drop in gardenias has been studied over a period of many years by numerous investigators, but despite this fact, not a single preventive measure has been advocated. Because of the unfruitfulness of past work with gardenias, in the present study the literature on bud and boll drop in cotton was investigated as the source of possible lines of study.

Mason (3) noted that shedding of bolls and buds was extremely high 5 days after heavy daytime rains associated with low evaporation rates. He felt that this shedding was the result of rapid changes in the water content of the tissues. Lloyd (2) also believed that changes in the water content of the plant were important. He pointed out that there is a large drop just after depletion of moisture in the deeper soil zones. He also stated that rains are responsible for bud drop by causing fluctuation in the soil moisture of the shallower soil zones.

Dunlop (1) placed a different interpretation on the bud and boll drop following heavy rains. He believed that this drop was due to the sharp fluctuations in light intensity when rainy weather followed the ordinary bright sunny days of the growing season. He demonstrated the apparent validity of his theory by bringing potted plants into a poorly lighted laboratory for a period of 4 days. When these plants were returned to the high illumination of the field, many buds and young bolls were shed, and by the end of the season there was a reduction of 75 per cent in the number of bolls maturing on these plants. Most of the shedding, however, occurred while the plants were in the low light conditions of the laboratory.

It would appear from a consideration of these several papers that any external environmental conditions, causing rapid fluctuations in the water content of the cotton plant might result in abscission of buds and bolls. This might also be the case with the gardenia.

Four treatments were applied in the present study. Some of the plants, all of which were grown in the greenhouse bench from May 1947 through June 1948, were watered daily so that no marked changes occurred in the water content of the soil. These plants were growing under ordinary light conditions, and, since insect control was handled by means of fumigation, the foliage was never wet. These plants were considered check plants and identified as series 1.

In series 2, plants were treated in a similar manner except that the soil was allowed to become moderately dry before being watered. Such a treatment should check the theory that bud drop might be caused by fluctuations in soil moisture.

In series 3, plants grown under ordinary light conditions and with continuously moist soil, were syringed with cold water on two consecutive days twice each month. It was presumed that such a treatment reduced leaf temperatures and possibly increased leaf

water content in the manner of a rain, although moisture content of the soil was already sufficiently high so that no changes could be expected from these small changes in soil moisture.

In the fourth series, plants were given moist soil conditions, but were shaded with a single thickness of heavy muslin for 5-day periods twice each month. This was intended to similate the light shock reported by Dunlop (1).

Plots consisted of three rows each, three plants per row. Rows were spaced 24 inches apart with 48 inches between plots. Despite this wide spacing, yields for the season amounted to 23 flowers per square foot of bench. All treatments except the check were replicated three times. Originally the check was also so planted, but it soon became apparent that one of the check plots, planted in a dark corner of the house, so nearly resembled a shaded plot that it was treated as a missing plot in the statistical analysis.

TABLE I—GARDENIAS PRODUCED IN 1947–48 SEASON

| Treatment | Flowers Per Plant | Buds Dropped Per Plant |
|---|---|---|
| Check | 69 | 12 |
| Alternately wet and dry | 70 | 11 |
| Foliage syringed | 68 | 12 |
| Intermittent shade | 52 | 14 |
| Significant difference 5 per cent level | 13 | 4 |

Analysis of variance indicated that yield of flowers from plants with intermittant shade was significantly lower than from any of the other treatments. A difference of 13 flowers was necessary to show significance at the 5 per cent level. Differences between treatment 4 and other treatments were not less than 16 flowers. There were no significant differences between any of the other treatments. Difference in bud-drop showed no significance in any treatment.

While shading gardenia plants for 5-day periods alternately with 10-day periods of normal light reduced the number of flowers produced, this could not be interpreted as resulting from shock since the check plot in the dark corner of the house produced only 43 flowers per plant and dropped an average of 17 buds. The reduction in flower production may more probably be interpreted as resulting from a reduction in total accumulated light received by the plants during their growing season.

## LITERATURE CITED

1. DUNLOP, A. A. Low light intensity and cotton boll-shedding. *Science* (n. s.) 98: 568–569. 1943.
2. LLOYD, F. E. Environmental changes and their effect upon boll-shedding in cotton. *Ann. N. Y. Acad. Sci.* 29: 1–131. 1920.
3. MASON, T. G. Growth and abscission in sea island cotton. *Ann. Bot.* 36: 458–484. 1922.

# Effect of Partial Defoliation on Flower Production of Better Times Roses

By J. R. KAMP, *University of Illinois, Urbana, Ill.*

IN recent work concerned with the incidence of blindness in the Better Times rose, it was noted that the only treatment greatly increasing the number of blind shoots was leaf removal. This defoliation was, however, accompanied by a marked increase in the number of shoots produced by the plant. In the more severe defoliation treatments, the rose plants produced four times the number of shoots found on untreated plants.

The type of defoliation practiced in the rose blindness study was rather severe in that leaves were continually removed during the development of the shoots. The quality of the flowers produced by such defoliated plants was markedly inferior and the percentage of blind shoots increased.

Since the total number of shoots was greatly increased by such defoliation, it was hoped that in this present study a very mild form of defoliation might slightly increase the number of shoots per plant without causing an increase in the percentage of blindness or a decrease in quality of flowers.

Twenty-eight Better Times rose plants formed a plot. Six plots were used as checks and six other plots, alternately placed, were defoliated. The flowers on all plots were cut in the usual manner, but when a flower was cut on a defoliated plot, all remaining leaves were removed from the stub. This meant the removal of three or four fully matured leaves from the base of each stem at the time the rose was cut. It also meant that all foliage was present during the development of the shoot so that there was ample opportunity for a normal carbohydrate supply to be stored in the basal stem tissue. It allowed for the removal of apical dominance in the stubs, permitting from two to four buds to break rather than one or two. The number of flowers produced, their stem length, and their keeping quality were noted and recorded throughout a season beginning October 1, 1947 and ending May 1, 1948.

The yield of flowers per plant for this period is shown in Table I.

TABLE I—BETTER TIMES ROSES CUT FROM CHECK AND DEFOLIATED PLOTS

| Treatment | Flowers Per Plant (Average of Six Plots) |
|---|---|
| Check | 17.0 |
| Defoliated | 16.1 |
| Significant difference 5 per cent level | 0.5 |
| Significant difference 1 per cent level | 0.8 |

Stem lengths of flowers cut from the check and defoliated plots were almost identical, averaging less than an inch difference. No differences were noted either in the size of bloom or in the keeping qualities of the flowers.

Analysis of variance showed the defoliation to be significant at the 1 per cent level for the combined plots.

It will be noted that, in spite of the fact that the number of shoots on the defoliated plants was approximately double that on the check plants, in all cases the defoliated plots yielded fewer flowers than the corresponding check plots. This was due to the fact that in many cases two or three blind shoots replaced a single strong shoot producing a flower when the defoliation was used. For this reason it appears that defoliation cannot be advocated as a means of increasing production of greenhouse roses and the seriousness of disease, such as black spot, which might cause the dropping of leaves on the rose plant is indicated.

# The Response of Greenhouse Roses to Various Oxygen Concentrations in the Substratum

By JOHN G. SEELEY, *Cornell University, Ithaca, N. Y.*

IN commercial rose production, plants are grown continuously for at least 4 or 5 years in a small volume of soil in benches, the plants being spaced 12 by 12 inches with the soil only 5 to 8 inches in depth. The soil is maintained at a high moisture content by frequent watering on the surface of the soil or by automatic means (31, 32).

When surface watered, the soil becomes packed and may restrict the diffusion of air into it. In addition, soils with a high moisture content may have a low air capacity, especially with the constant water level method of watering (32). In this system a constant water table is maintained about ½ to 1 inch below the soil in the bench. Therefore the lower inch or two of soil is extremely wet and it does not seem likely that the air content of this portion of the soil would be very great.

Little is known about the actual aeration conditions in greenhouse rose soils. Likewise practically nothing is known about the oxygen requirements of roses. The following investigation was undertaken to study the response of greenhouse roses to various concentrations of oxygen in the root medium. It is realized that consideration of the carbon dioxide content of the soil atmosphere as a factor affecting plant growth should not be neglected, but in order to segregate oxygen responses, the carbon dioxide was kept at a minimum.

In a review of the literature previous to 1925 Clements (11) and Cannon (8) discussed the oxygen and carbon dioxide effects on plant growth processes and stressed the importance of an adequate oxygen supply for the vital activities of plant roots. The literature on this subject has been recently reviewed by Seeley (36).

Anatomical changes in plants under various oxygen conditions have been observed by many investigators. Several (13, 16, 20, 27, 40) have observed that root hair production is favorably influenced by good aeration conditions. Others (2, 15, 28, 38) observed and studied the development of air cavities in root tissues of plant growing under low oxygen conditions.

The rather meager literature on aeration as it affects water absorption and transpiration was discussed by Clements (11) in 1921 and Kramer (26) in 1945. Reduction of the oxygen supply to roots has been observed to cause decreased absorption of water by plants followed by wilting. Kramer pointed out that poor soil aeration not only reduced absorption of transpiring plants by causing a decrease in permeability of the roots, but also by decreasing the absorbing surface as a result of cessation of root growth and death of roots.

The effect of aeration on salt absorption and accumulation has been studied by many workers notably Hoagland and his co-workers (6, 23, 24, 25), Steward and his associates (42, 43), Petrie (30), Rosenfels (34), Shive and his co-workers (18, 29, 37), Chang and Loomis (9), and Compton (12). Their results show that a supply of oxygen is necessary for salt absorption and accumulation by plants.

In a study of the aeration of rose garden soils, Boicourt and Allen (3) placed 4-inch tile at a depth of 10 inches underneath rose beds. Aeration of the soil was accomplished by glass wool channels, 3 inches in diameter, connected to the tile every 2 feet and extending vertically to the surface of the soil. Air was forced through the tile with a vacuum cleaner blower for a period of 1 hour each morning (7 to 8 a. m.). Analyses of the atmosphere of non-aerated soils at a depth of 8 inches averaged about 18.8 to 19.3 per cent oxygen and 1.5 to 1.9 per cent carbon dioxide, whereas aerated soils contained 20.2 to 20.3 oxygen and 0.3 to 0.6 per cent of carbon dioxide. The total linear growth of plants in aerated soils was almost double that in non-aerated soils. The authors stated that because a small difference in measured oxygen concentration caused such great differences in growth, either the rose was sensitive or the technique was not accurate enough.

Ray and Shanks (33) in studies of the aggregation and aeration of some greenhouse soil mixtures for roses found relatively large differences in the oxygen and carbon dioxide content of the soil atmosphere ranging from 14 to 20.5 per cent oxygen and 0.3 to 3 per cent carbon dioxide with several different methods of soil preparation, mulching, and watering. They reported no significant differences in production of roses under the treatments given.

## Methods and Materials

To obtain the growth response of roses to definite oxygen concentrations in the root medium, gases of known oxygen concentration were passed continuously through a coarse soil in experiments 1 and 2 and through liquid nutrient cultures in experiments 3 and 4.

*Soil Culture Experiments:*—Stem cuttings of greenhouse roses, variety Better Times, were rooted in expanded Vermiculite and grown in a well prepared potting soil for 3 to 6 weeks. Uniform plants were then selected and the soil carefully removed from the roots before planting in a coarse soil having a medium nutrient supply and an organic matter content of 8.1 per cent. There were 10 plants in each treatment, with two plants per culture.

A gas being forced through an ordinary soil would probably pass through a few large pores rather than thoroughly permeating the entire soil mass. Therefore, the plants were grown in a soil composed of coarse aggregates obtained by screening air dry soil through a ⅜-inch screen to remove large aggregates and then through a ⅛-inch screen to remove the smaller aggregates and particles. With this type of soil one can expect good distribution of air throughout the culture with the greatest distance between a root and the soil, atmosphere in the large pores being $^3/_{16}$ inch. At the end of the experiments, many roots were found on the surface of the aggregates, and therefore were directly exposed to the gas mixture being supplied. The pore space was calculated to be about 700 cc.

Fruit juice cans 18 cm high and 10 cm in diameter (Fig. 1) were coated on the inside with horticultural asphalt paint. A glass wick was forced through a piece of glass tubing inserting through a rubber stop-


FIG. 1. Roses grown in soil aerated with gas mixtures containing 1, 5, 10, and 21 per cent oxygen. Photographed June 23, 1947.

per in the bottom of the can; the end was frayed out on the surface of 2 cm of pea gravel. An inlet of 5 mm glass tubing entered the top of the can and was connected to a glass Y, the two outlets of which were located in the gravel on diametrically opposite sides of the can. The gravel aided in distributing the aerating gas throughout the bottom of the can before it passed through the soil. Coarse soil was placed on the gravel and as the culture container was filled to within 2 cm of the top of the can, two plants were placed with the roots about 3.5 to 7.5 cm below the surface of the soil. The soil aggregates were settled by a gentle tapping of the can and lightly watered.

In three of the five cultures in each treatment a thermometer and a gas sampling well similar to that of Boynton and Reuther (5) were placed with the lower end 8 to 9 cm below the soil surface.

The cultures were spaced about 15 cm apart over troughs containing water which rose through the wicks, automatically keeping the soil moist. The tubing in which the wick had been inserted extended below the surface of the water to prevent diffusion of air in through the bottom of the culture. Nutrients were supplied by substituting a complete nutrient solution for the subirrigation water in the troughs every 3 weeks.

The aerating gas from the cultures bubbled through a water trap which prevented backward diffusion of air through the outlet. The cultures were sealed with a 2: 1 mixture of paraffin and petrolatum.

The aerating gases were mixtures of nitrogen (water-pumped) and oxygen supplied as compressed gas mixtures in cylinders. Air which contains 20.7 per cent oxygen was used for the 21 per cent oxygen gas mixture.

In the first experiment the gas mixtures were supplied at the rate of 5, 10, and 20 liters per day in order to determine the rate necessary to maintain a constant oxygen concentration and a low carbon dioxide concentration in the soil atmosphere. Twelve liters per day were used in the second soil experiments.

In experiment 1, no provision was made for temperature control except that the culture cans were coated with aluminum paint and shaded from the direct sun with two thicknesses of cheese cloth. The temperature in the cultures ranged from 16.5 degrees to a maximum of 29 degrees C, the latter occurring in the middle of the day at two times. The temperatures generally were from 16 to 20 degrees C at night and 17 to 24 degrees C in the daytime. In the three subsequent experiments the temperature of the cultures was maintained between 18 and 20 degrees C by means of a thermostatically controlled water bath.

The oxygen and carbon dioxide concentrations in the soil atmosphere were determined by the Haldane method (21). Growth was judged on the basis of general appearance on the plants, linear shoot development and dry weight of roots and shoots (oven dried at 110 degrees C for 24 hours). Standard deviation and least significant difference values obtained by analysis of variance were determined by methods outlined by Snedecor (39).

*Nutrient Culture Experiments:*—The roots of plants similar to those used in the soil experiments were washed free of soil and transferred to nutrient solution in equilibrium with normal air. The nutrient solution was a slight modification of a solution which previously (35) produced excellent growth of roses (Table I). Micro-elements, except for iron, were supplied by the minor element solution of Hoagland (22). Iron as ferrous sulphate and ferric ammonium citrate was added to the solution at the rate of 0.5 ppm every other day just before filling the nutrient solution reservoirs. The two forms of iron were used alternately.

TABLE I—COMPOSITION OF NUTRIENT SOLUTION

| Salt | Cc of M/2 Stock Solution Per Liter of Solution |
|---|---|
| $Ca(NO_3)_2 \cdot 4H_2O$ | 2.50 |
| $NaNO_3$ | 6.50 |
| $MgSO_4 \cdot 7H_2O$ | 4.70 |
| $KH_2PO_4$ | 6.90 |

The solution was supplied by the standard continuous flow method with a 1.7 liter culture vessel (Fig. 4) and apparatus similar to that

described by Gilbert and Shive (18). A 5-cm length of 2-cm porous carbon tubing was attached to the inlet tube to break the gas into many fine bubbles.

The solutions were maintained at 18 to 20 degrees C. Twelve liters of gas per culture per day were sufficient to maintain the solutions in equilibrium with the aerating gases. The oxygen content of the solutions was determined once a week by the Winkler method (41) as modified by Allison and Shive (1).

## Results

### Experiment 1 (Soil)

The soils were aerated with gas mixtures containing approximately 1, 5, 10, and 21 per cent oxygen at the rate of 5, 10, and 20 liters of gas per culture per day. Analyses showed (Table II) that with these rates of flow the oxygen content of the soil atmosphere was constant and only slightly below that of the aerating gas. The carbon dioxide tended to decrease as the rate of flow increased from 5 to 20 liters per day. The highest carbon dioxide concentration was, however, only 2.12 per cent and in most analyses was less than 1 per cent. It is believed that the carbon dioxide concentration was sufficiently low in all cultures so that it probably was having no appreciable effect on the plant growth, except possibly the 5 liters per day of 1 per cent oxygen treatment where the carbon dioxide concentration was as great or greater than the oxygen.

*Shoot Growth:*—The total linear growth of the shoots of the plants during the 37-day experimental period was greatest with 21 per cent oxygen in the aerating gas and decreased as oxygen content was reduced (Table II). The difference in growth between the 10 and 21 per cent $O_2$ treatments was not significant; the reduction in shoot growth with 5 per cent $O_2$ was only slightly significant while there

TABLE II—Effect of Aeration Treatment Upon the Growth of Roses in Soil (May 17 to June 23, 1947)

| Aeration Treatment | | Analysis of Soil Atmosphere (Per Cent) | | Average Increase in Shoot Growth (Cm) | Average Final Dry Weight (Grams) | |
|---|---|---|---|---|---|---|
| Oxygen in Aerating Gas (Per Cent) | Rate of Flow (Liters Per Day) | Oxygen | Carbon Dioxide | | Shoots | Roots |
| 1 | 5 | 1.10– 1.22 | 1.14–2.12 | 2.15 | 2.60 | 0.44 |
| 1 | 10 | 1.04– 1.22 | 0.48–0.87 | 1.87 | 2.40 | 0.42 |
| 1 | 20 | 1.10– 1.23 | 0.35–0.52 | 1.20 | 1.91 | 0.44 |
| 5 | 5 | 4.47– 4.80 | 0.80–1.12 | 18.85 | 4.81 | 0.98 |
| 5 | 10 | 4.78– 4.96 | 0.42–0.66 | 17.20 | 5.71 | 1.11 |
| 5 | 20 | 4.88– 4.96 | 0.17–0.52 | 19.00 | 5.05 | 1.23 |
| 10 | 5 | 8.35– 9.02 | 0.80–1.06 | 23 75 | 4.82 | 1.08 |
| 10 | 10 | 9.52– 9.96 | 0.38–0.62 | 20.50 | 4.61 | 0.90 |
| 10 | 20 | 9.68– 9.90 | 0.20–0.54 | 23.90 | 4.95 | 1.05 |
| 21 | 5 | 19.86–20.48 | 0.38–0.72 | 26.85 | 4.42 | 0.99 |
| 21 | 10 | 19.65–20.45 | 0.42–0.74 | 29.30 | 5.52 | 0.94 |
| 21 | 20 | 20.04–20.60 | 0.31–0.54 | 29.40 | 6.40 | 1.08 |
| Original plants ± standard deviation................ | | | | —— | 1.76 ± 0.53 | 0.30 ± 0.02 |
| Least significant difference, 1 per cent.............. | | | | 11.55 | 2.26 | 0.41 |
| Least significant difference, 5 per cent.............. | | | | 8.73 | 1.70 | 0.31 |

was a very significant reduction in shoot growth with only 1 per cent $O_2$ in the aerating gas.

There was little difference in shoot growth due to the different rates of flow of a particular gas; this would be expected because the gas analyses had shown only slight variations in the oxygen content of the atmosphere with the different rates of flow.

Plants receiving 5, 10, and 21 per cent oxygen gas mixtures all produced excellent shoot growth, were well branched, and had good green foliage (Fig. 1).

The shoot growth of roses in the 1 per cent oxygen cultures was drastically retarded after 10 days of treatment and ceased after 30 days. The foliage remained dark green during the first 3 weeks of the low oxygen treatment; then the lower foliage and later the leaves farther up the plant became light green. The leaflets became yellow along the midrib and veins, and finally the entire leaf turned yellow. The leaflets subsequently turned brown along the midrib, then along the veins, and the entire leaflet turned brown. Young shoots which were apparently in vigorous growing condition at the start of the oxygen treatment did not elongate.

The dry weight of the shoots was not significantly different with 5, 10, and 21 per cent oxygen, but was greatly reduced with only 1 per cent $O_2$ in the soil atmosphere (Table II).

*Root Growth:*—Except for a few small white roots, all of the roots of plants in the 1 per cent oxygen treatments were dead when harvested (Fig. 1). The roots of plants receiving the higher concentrations of oxygen were profusely branched and well developed with many new white roots. Little difference was evident with 5, 10, and 21 per cent oxygen and the various rates of flow; the dry weight data substantiate this observation.

## Experiment 2 (Soil)

Soil cultures were aerated at the rate of 12 liters per day with gas mixtures containing 1, 5, 10 and 21 per cent oxygen. To study the effect of rate of flow as well as oxygen concentration, the 5 and 21 per cent oxygen gas mixtures were also supplied at the rate of 1 liter per day. The more rapid flow maintained the desired oxygen concentrations and prevented accumulation of large amounts of carbon dioxide (Table III). With the slow rate of flow of the 5 per cent oxygen mixtures, analyses indicated the soil atmosphere to have only 2 to 3 per cent oxygen and carbon dioxide from 2 to 5 per cent. With the slow flow of the 21 per cent oxygen mixture, the soil atmosphere contained only 10 to 14 per cent oxygen, and carbon dioxide accumulated to a concentration of 5 to 12 per cent.

*Shoot Growth:*—On December 20, 3 weeks after the gas treatments were started, new shoots started to develop on the plants in the 10 and 21 per cent oxygen treatments, but the axillary buds of those plants with the lower oxygen concentrations did not grow.

A week later the older leaves on the plants in the 1 per cent oxygen series and the 1 liter per day of 5 per cent oxygen series (2 to 3 per

TABLE III—EFFECT OF AERATION TREATMENT UPON THE GROWTH OF ROSES IN SOIL (DEC 1, 1947 TO FEB 20, 1948)

| Aeration Treatment | | Analysis of Soil Atmosphere (Per Cent) | | Average Increase in Shoot Growth (Cm) | Average Final Dry Weight (Grams) | |
|---|---|---|---|---|---|---|
| Oxygen in Aerating Gas (Per Cent) | Rate of Flow (Liters Per Day) | Oxygen | Carbon Dioxide | | Shoots | Roots |
| 1* | 12 | 0.85– 1.05 | 0.37– 1.02 | 0.10 | 1.04 | 0.39 |
| 5* | 1 | 2.06– 3.02 | 1.92– 5.28 | 0.20 | 1.04 | 0.49 |
| 5 | 12 | 4.45– 4.93 | 0.42– 1.02 | 16.10 | 3.64 | 0.75 |
| 10 | 12 | 8.76– 9.92 | 0.40– 1.15 | 46.30 | 5.43 | 1.36 |
| 21 | 1 | 9.86–13.80 | 4.70–12.13 | 38.25 | 5.41 | 1.17 |
| 21 | 12 | 19.02–20.36 | 0.48– 1.07 | 42.15 | 5.77 | 1.57 |
| Original plants ± standard deviation | | | | —— | 1.26 ± 0.22 | 0 28 ± 0.02 |
| Least significant difference, 1 per cent | | | | 8.63 | 0.99 | 0.40 |
| Least significant difference, 5 per cent | | | | 6 52 | 0.75 | 0.30 |

*Harvested Jan 19, 1948; all others harvested Feb 20.

cent oxygen in the soil atmosphere) started to show oxygen deficiency symptoms as previously described. Only one plant in each of these two treatments developed any new shoots after the gas treatments were started (Fig. 2). These were blind shoots only 1 to 2 cms long. The linear growth and the dry weight of the shoots of these plants were very small and almost the same for both treatments (Table III).

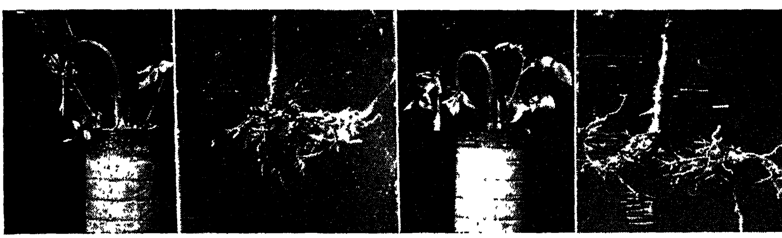

FIG. 2. Roses grown in soil. Left, aerated with 12 liters per day of 1 per cent oxygen. Right, 1 liter per day of 5 per cent oxygen. Photographed January 19, 1948.

Rose plants in the 12 liters per day of 5 per cent oxygen and in the three 10 and 21 per cent oxygen treatments had good green foliage and considerable new shoot growth with little difference between the 10 and 21 per cent oxygen treatments (Fig. 3). Plants in this 5 per cent oxygen series did not grow as well as with the higher oxygen concentrations. At the end of the experiment, the plants with approximately 5 per cent oxygen around the roots still had good foliage color but the shoot growth had been retarded and was significantly less than with the 10 and 21 oxygen aeration treatments (Table III). There was no significant difference in shoot growth and dry weight of the shoots of plants in the 10 per cent and the two 21 oxygen treatments.

Plants with the slow rate of flow of the 21 per cent oxygen gas mixture had a greater oxygen and carbon dioxide concentration around the roots than with the more rapid flow of the 10 per cent oxygen gas. The former plants, however, had slightly less shoot growth and less dry weight of shoots and roots than the latter. The differences were

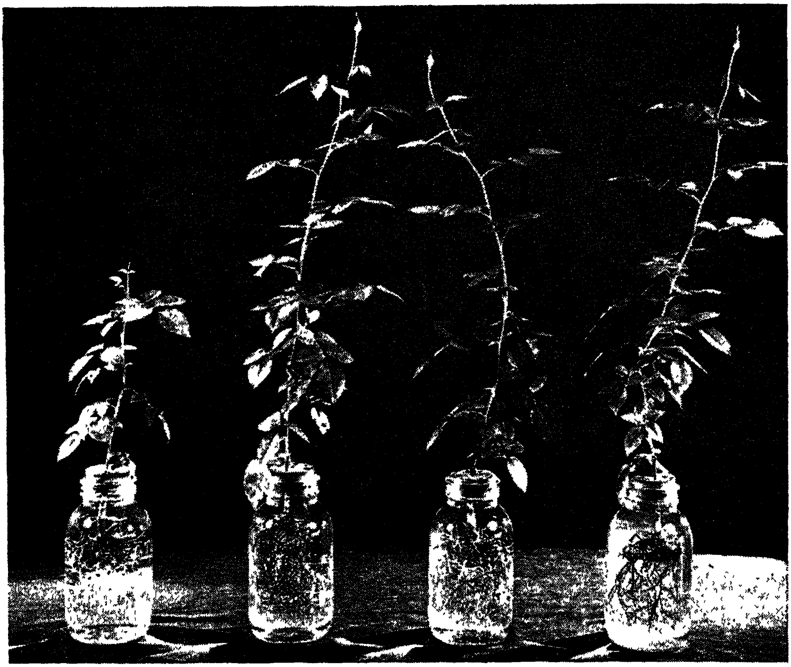

FIG. 3. Roses grown in soil. Left to right: 12 liters per day of 5 per cent oxygen, 12 liters per day of 10 per cent oxygen, 1 liter per day of 21 per cent oxygen, and 12 liters per day of 21 per cent oxygen gas mixtures. Photographed February 20, 1948.

small and it is not definitely known whether the higher carbon dioxide concentration was having a slight retarding effect on growth.

*Root Growth:*—When harvested, the roots of plants with 1 and 2 to 3 per cent oxygen around the roots were dead and appeared to have made little or no new growth (Fig. 2). The dry weight data substantiate this observation.

Plants with almost 5 per cent oxygen in the soil atmosphere formed many well branched roots with many root hairs, but the root systems were significantly smaller than with the higher oxygen concentrations (Table III and Fig. 3). There was no significant difference in the dry weight of the roots of plants grown with 10 and 21 per cent oxygen in the aerating gas.

## EXPERIMENT 3 (NUTRIENT SOLUTION)

By aerating the solutions with 12 liters of the gas mixtures per culture per day and maintaining a constant temperature, nearly constant concentrations of dissolved oxygen were maintained in the nutrient solution (Table IV).

*Shoot Growth:*—Four days after the start of the oxygen treatments, all plants commenced to form new shoots but 6 days later those plants

in solutions aerated with the 1 and 5 per cent oxygen gas mixtures appeared to be developing more slowly than the plants in the higher oxygen treatments.

Three weeks later, plants in the 10 and 21 per cent oxygen treatments had developed many new shoots with good green foliage; the 21 per cent oxygen plants were a little larger than those with 10 per cent oxygen in the aerating gas. Four of the 5 per cent plants had good green color, whereas six were becoming chlorotic with green veins and a light yellowing between the veins. This was a typical iron chlorosis in spite of the fact that the nutrient solutions contained adequate amounts of iron. Growth was definitely retarded.

The plants with the 1 per cent oxygen aeration treatment also had made little growth. Nearly all of the older leaves which were on the plant at the start of the experiment were still green, but the new growth was chlorotic. A few of the older leaves showed a slight iron chlorosis, and some were almost completely yellow with brown areas along the midrib similar to those of the oxygen deficient plants in the soil experiments.

At the end of the experiment plants in the 1 and 5 per cent oxygen treatments were not branched and had produced only one very short blind shoot (Fig. 4); in fact, shoot growth ceased after 3 weeks of treatment. All of the mature leaves were yellow with brown areas along the midrib and veins; the younger leaves were yellow with light green veins.

Plants in the 21 per cent oxygen series were well branched and had excellent green foliage; those in solutions aerated with the 10 per cent oxygen gas mixture were similar but slightly smaller. The plants in both treatments were growing vigorously when harvested.

FIG. 4. Roses grown in nutrient solutions aerated with gases of different oxygen content. Left to right: 1, 5, 10, and 21 per cent oxygen. Photographed November 3, 1947.

The linear shoot growth and the dry weight of shoots were greatest with 21 per cent oxygen in the aerating gas and decreased as the oxygen concentration decreased (Table IV).

*Root Growth:*—The roots of plants in nutrient solutions containing approximately 4 and 9 ppm of dissolved oxygen were well branched, white, and almost filled the culture jars (Fig. 4). The roots in solutions in equilibrium with 1 per cent oxygen turned brown within 5 days after the start of the treatments, and 10 days later many roots were dead. With 5 per cent oxygen in the aerating gas the roots were not injured so quickly. After 25 days, however, many were black and dead, but some of the small roots were short, stubby, and white. When harvested, practically all were dead.

The dry weight of the roots increased with each increment of oxygen concentration in the nutrient solution (Table IV). In solutions aerated with the 1, 5, and 10 per cent oxygen gas mixtures, the dry weight was significantly less than with the 21 per cent oxygen; the roots of plants in the 10 per cent oxygen treatment, however, were well developed and actively growing, when harvested.

TABLE IV—EFFECT OF AERATION TREATMENT UPON THE GROWTH OF ROSES IN NUTRIENT SOLUTION (SEP 25 TO NOV 3, 1947)

| Oxygen in Aerating Gas (Per Cent) | Dissolved Oxygen (Ppm) | Average Increase in Shoot Growth (Cm) | Average Final Dry Weight (Grams) | |
|---|---|---|---|---|
| | | | Shoots | Roots |
| 1 | 0.29–0.43 | 6.50 | 2.97 | 0.34 |
| 5 | 2.05–2.18 | 8.60 | 3.14 | 0.45 |
| 10 | 4.18–4.38 | 26.60 | 5.09 | 0.84 |
| 21 | 8.80–9.20 | 54.90 | 6.84 | 1.29 |
| Original plants ± standard deviation | | — | 1.71 ± 0.14 | 0.24 ± 0.01 |
| Least significant difference, 1 per cent | | 17.18 | 1.51 | 0.31 |
| Least significant difference, 5 per cent | | 12.72 | 1.13 | 0.23 |

## EXPERIMENT 4 (NUTRIENT SOLUTION)

The aerating gases contained 5, 10, 15, and 21 per cent oxygen and the results were similar to those of the previous experiment. Again shoot and root growth was best in the solution aerated with 21 per cent oxygen and decreased as the oxygen content of the solution decreased (Table V and Fig. 5). Plants in solutions aerated with the 5 per cent oxygen mixture became light green after 2 weeks of treatment and

TABLE V—EFFECT OF AERATION UPON THE GROWTH OF ROSES IN NUTRIENT SOLUTION (FEB 23 TO MAY 3, 1948)

| Oxygen in Aerating Gas (Per Cent) | Dissolved Oxygen (Ppm) | Average Increase in Shoot Growth (Cm) | Average Final Dry Weight (Grams) | |
|---|---|---|---|---|
| | | | Shoots | Roots |
| 5 | 2.01–2.27 | 24.50 | 3.00 | 0.65 |
| 10 | 4.08–4.41 | 78.10 | 7.70 | 1.63 |
| 15 | 6.51–6.72 | 94.90 | 10.43 | 2.02 |
| 21 | 8.76–9.13 | 174.40 | 18.88 | 3.23 |
| Original plants ± standard deviation | | — | 1.48 ± 0.46 | 0.31 ± 0.09 |
| Least significant difference, 1 per cent | | 49.00 | 2.56 | 0.853 |
| Least significant difference, 5 per cent | | 36.30 | 1.90 | 0.9 |

later were chlorotic. At the end of the experiment all except a few short, stubby, unbranched roots were dead.

All of the plants in the 10, 15, and 21 per cent oxygen treatments grew vigorously and were well branched with excellent dark green foliage. There was little difference in shoot and root growth with 10 and 15 per cent oxygen in the aerating gas. The plants in the 21 per cent oxygen treatment (9 ppm of dissolved oxygen) were significantly better in root and shoot development than plants with less oxygen. The roots of plants in these three treatments were extensive, well branched and white (Fig. 5).

FIG. 5. Roses grown in nutrient solutions aerated with gases of different oxygen content. Left to right: 5, 10, 15, and 21 per cent oxygen. Photographed May 3, 1948.

## Discussion

The rose plants demonstrated a very definite response to the different concentrations of oxygen in the substratum. Plants in soil cultures with a soil atmosphere containing 1 per cent and 2 to 3 per cent oxygen were retarded in shoot growth shortly after the low oxygen treatment started. After about 4 weeks, shoot growth ceased completely; oxygen deficiency symptoms appeared, and the roots were dead. A similar retardation of root growth was reported by Cannon (7) who found that onion roots stopped growth with 2 per cent oxygen, and elongation of many other species was slowed to a marked degree.

Roses in soil with a 5 per cent oxygen atmosphere started to grow at the same rate as the 10 and 21 oxygen plants but later shoot growth was retarded until at the end of the experiments the 5 per cent oxygen plants were considerably smaller than the 10 and 21 per cent oxygen plants. There were, however, no definite deficiency symptoms. The foliage color was good and unless compared with other treatments it would not have been known that these plants were being affected by a lack of sufficient oxygen. This is of practical importance because in a greenhouse soil, the soil oxygen status may be such that growth and flower production is being retarded but it would be difficult to recognize the cause of the retardation.

The shoot and root growth of roses with a soil atmosphere of 10 and 21 per cent oxygen was not significantly different, being very good in both treatments.

In nutrient solution, the results were somewhat different. Again plants grew well when the root medium was aerated with atmospheres of 10 and 21 per cent oxygen but the shoot and root growth decreased with each decrease in the oxygen content of the aerating gas from 21 down to 1 per cent.

Plants in soil aerated with 5 per cent oxygen atmospheres made fairly good growth, but plants in nutrient solutions aerated with similar 5 per cent oxygen gas mixtures were small and had few new shoots and roots. The first chlorosis to appear in nutrient solutions was a yellowing of the leaves with the veins remaining green, a typical iron chlorosis, even though iron was being supplied. The injury to the roots due to the deficiency of oxygen may have decreased the efficiency with which the plants absorbed iron. Previous experience with roses indicates that iron deficiency caused by some adverse condition such as root injury, unbalanced nutrient conditions, and pH generally appears in nutrient culture sooner than in soil culture.

Boicourt and Allen (3) found that plants in aerated garden soils with 20.2 to 20.3 per cent oxygen and 0.3 to 0.6 per cent carbon dioxide in the soil atmosphere produced twice as much shoot growth as plants in unaerated soils with 18.8 to 19.3 per cent oxygen and 1.5 to 1.9 per cent carbon dioxide. The results of the present investigation indicate that the rose is not sensitive to such small differences in the oxygen supply and that some other factor was causing the difference in growth. It should be realized that the method of sampling the soil atmosphere used by Boicourt and Allen was similar to that of Boynton and Reuther (5). By this method the air would probably be pulled out of the larger soil pores and the analyses would not necessarily show the oxygen conditions in the soil in close proximity of the roots and in the smaller pores. Another factor that should be considered is that the roses used by Boicourt and Allen were budded on *Rosa multiflora* variety japonica and that this stock may differ in oxygen requirements from the own root plants of the Hybrid Tea type used in the present investigations. Greenhouse roses are often budded or grafted on Manettii *(Rosa Noisettiana)* stock plants which likewise may have different oxygen requirements.

The results obtained with roses were similar to those reported for apple trees. DeVilliers (14) found that apple seedlings with 5 per cent oxygen in the soil atmosphere had only 50 per cent of the dry weight of plants with 20.6 oxygen, and only 35 per cent with 1 per cent oxygen. Boynton (4) reported that the growth of 1-year-old budded apple trees was retarded with oxygen below 10 per cent. Childs (10) found no depressing effect on the growth of 1- and 2-year-old budded apple trees until the oxygen content of the soil atmosphere was reduced to 12 per cent or slightly less. There was a very little growth even with 1.5 per cent. Compton (12) more recently reported that in nutrient solutions at 26 degrees C, the growth of apple trees increased with each increment of oxygen in the solution until in equilibrium with 5 per cent oxygen and further increases up to 21 per cent oxygen caused little more increase in growth. He also found that the chlorophyll content of the leaves increased directly with increments of the oxygen tension of the nutrient solution.

Roses in nutrient solution grew best when the solution contained approximately 9 ppm of oxygen and although growth was significantly reduced with 4 ppm of dissolved oxygen, the root and shoot develop-

ment was good. With a range of about 0.35 to 2.0 ppm of dissolved oxygen, growth was greatly inhibited and the plants were injured.

Soybeans were found by Shive (37) and Gilbert and Shive (18) to grow best with 6 to 8 ppm oxygen, oats with 8 ppm, and tomatoes with 16 ppm oxygen in the nutrient solution. Erickson (17) reported that tomatoes in nutrient solution were reduced in growth as the oxygen content of the aerating gas was reduced below 21 per cent. Taylor (44) observed that the development of wheat decreased rapidly as the oxygen content of the aerating gas was reduced from 20.8 to 10.4 per cent; rice was not seriously inhibited until the oxygen was reduced below 5.2 per cent. Vlamis and Davis (45) similarly reported maximum growth of rice seedlings with a 5 per cent oxygen aerating atmosphere with a decline at lower levels of oxygen. Barley seedling growth declined rapidly as the oxygen content of the aerating gas was reduced below 9.5 per cent. From these reports it may be seen that the rose apparently has a higher oxygen requirement than some plants like rice, less than others such as the tomato, and about the same as many plants.

## Summary

1. Roses in soil and nutrient solution aerated with gas mixtures containing 1 per cent oxygen produced little new shoot growth and exhibited a foliar chlorosis. The root systems were nearly or completely dead at the end of the experiments.

2. Plants in soils aerated with 5 per cent oxygen gas grew fairly well and although somewhat inhibited in shoot growth, no specific oxygen deficiency symptoms were apparent. The root systems were good, but not as extensive as with 10 and 21 per cent oxygen.

3. Plants in nutrient solutions aerated with 5 per cent oxygen gas were similar to those with 1 per cent oxygen, making little new shoot growth and becoming chlorotic.

4. In both soil and nutrient solution, the greatest root and shoot development was obtained when the cultures were aerated with gas mixtures containing 10 and 21 per cent oxygen. In soil there was no significant difference between the 10 and 21 per cent oxygen treatments. In nutrient solution, however, the shoot and root development of plants in solutions aerated with the 21 per cent oxygen gas was greater than with 10 or 15 per cent oxygen.

## Literature Cited

1. Allison, R. V., and Shive, J. W. Micro-sampling for the determination of dissolved oxygen. *Soil Sci.* 17: 97–105. 1923.
2. Andrews, F. M., and Beal, C. C. The effect of soaking in water and of aeration on the growth of *Zea Mays*. *Bul. Torr. Bot. Club* 46: 91–100. 1919.
3. Boicourt, A. W., and Allen, R. C. Effect of aeration on growth of hybrid tea roses. *Proc. Amer. Soc. Hort. Sci.* 39: 423–425. 1941.
4. Boynton, D. Soil atmosphere and the production of new rootlets by apple tree root systems. *Proc. Amer. Soc. Hort. Sci.* 37: 19–26. 1940.
5. ———— and Reuther, W. A way of sampling soil gases in dense subsoils and some of its advantages and limitations. *Proc. Soil Sci. Soc. Amer.* 3: 37–42. 1939.

6. BROYER, T. C., and HOAGLAND, D. R. Metabolic activities of roots and their bearing on the relation of upward movement of salts and water in plants. *Amer. Jour. Bot.* 30: 261–273. 1943.
7. CANNON, W. A. Effect of a diminished oxygen supply on the rate of growth of roots. *Carnegie Inst. Wash. Yearbook* 19: 59–61. 1920.
8. ———— Physiological features of roots, with especial references to the relation of roots to aeration of the soil. *Carnegie Inst. Wash. Pub.* 368. 1925.
9. CHANG, H. T., and LOOMIS, W. E. Effect of carbon dioxide on absorption of water and nutrients by roots. *Plant Phys.* 20: 221–232. 1945.
10. CHILDS, W. H. Photosynthesis, transpiration, and growth of apple trees as influenced by various concentrations of oxygen and carbon dioxide in the soil atmosphere. *Proc. Amer. Soc. Hort. Sci.* 38: 179–180. 1941.
11. CLEMENTS, F. H. Aeration and air content. The role of oxygen in root activity. *Carnegie Inst. Wash. Pub.* 315. 1921.
12. COMPTON, O. C. Aeration and salt absorption by young apple trees. Cornell University Ph.D. Thesis. 1947.
13. DEAN, B. E. Effect of soil type and aeration upon root systems of certain aquatic plants. *Plant Phys.* 8: 203–222. 1933.
14. DE VILLIERS, J. I. Some responses of McIntosh apple seedlings growing with the roots in various concentrations of oxygen. *Proc. Amer. Soc. Hort. Sci.* 36: 86. 1939.
15. DUNN, G. Note on the histology of grain roots. *Amer. Jour. Bot.* 8: 207–211. 1921.
16. DURELL, W. D. The effect of aeration on growth of the tomato in nutrient solution. *Plant Phys.* 16: 327–341. 1941.
17. ERICKSON, L. C. Growth of tomato roots as influenced by oxygen in the nutrient solution. *Amer. Jour. Bot.* 33: 551–561. 1946.
18. GILBERT, S. G., and SHIVE, J. W. The significance of oxygen in nutrient substrates for plants: I. the oxygen requirement. *Soil Sci.* 53: 143–152. 1942.
19. ———— The importance of oxygen in the nutrient substrate for plants-relation of the nitrate ion to respiration. *Soil Sci.* 59: 453–460. 1945.
20. GIRTON, R. E. The growth of citrus seedlings as influenced by environmental factors. *Univ. Cal. Pub. Agr. Sci.* 5: 83–117. 1927.
21. HALDANE, J. S., and GRAHAM, J. I. Method of Gas Analysis. Chas. Griffin and Co., Ltd., London. 1935.
22. HOAGLAND, D. R. The water-culture method for growing plants without soil. *Calif. Agr. Exp. Sta. Cir.* 347. 1938.
23. ———— Salt accumulation by plant cells with special reference to metabolism and experiments on barley roots. *Symposia on Quant. Biol.* 8: 181–194. 1940.
24. ———— and BROYER, T. C. General nature of the process of salt accumulation by roots with description of experimental methods. *Plant Phys.* 11: 471–507. 1936.
25. ———— Hydrogen ion effects and the accumulation of salt by barley roots as influenced by metabolism. *Amer. Jour. Bot.* 27: 173–185. 1940.
26. KRAMER, P. J. Absorption of water by plants. *Bot. Rev.* 11: 310–355. 1945.
27. LOEHWING, W. F. Physiological aspects of the effects of continuous soil aeration on plant growth. *Plant Phys.* 9: 567–583. 1934.
28. MCPHERSON, D. C. Cortical air spaces in the roots of *Zea Mays* L. *New Phytol.* 38: 190–202. 1939.
29. PEPKOWITZ, L. P., and SHIVE, J. W. The importance of oxygen in the nutrient substrate for plants-ion absorption. *Soil Sci.* 57: 143–154. 1944.
30. PETRIE, A. K. H. The intake of ions by the plant and its relation to the respiration of the root. *Australian Jour. Biol. Med. Sci.* 11: 25–34. 1933.
31. POST, K., and SEELEY, J. G. Automatic watering of greenhouse crops. *N. Y. (Cornell) Exp. Sta. Bul.* 793. 1943.
32. ———— The constant water level method of watering roses. *Proc. Amer. Soc. Hort. Sci.* 49: 441–443. 1947.

33. RAY, S. H., and SHANKS, J. B. The aggregation and aeration of some greenhouse soil mixtures for roses and carnations. *Proc. Amer. Soc. Hort. Sci.* 49: 420–426. 1947.
34. ROSENFELS, R. The absorption and accumulation of potassium bromide by Elodea as related to respiration. *Protoplasma* 23: 503–519. 1935.
35. SEELEY, J. G. Interrelationships of calcium and phosphorus concentrations and the growth and composition of the rose. Rutgers University M.Sc. Thesis. 1940.
36. ———— Some responses of greenhouse roses to various oxygen concentrations in the substratum. Cornell University Ph.D. Thesis. 1948.
37. SHIVE, J. W. The balance of ions and oxygen tension in nutrient substrates for plants. *Soil Sci.* 51: 445–449. 1941.
38. SIFTON, H. B. Air space tissues in plants. *Bot. Rev.* 11: 108–143. 1945.
39. SNEDECOR, G. W. Statistical Methods. Iowa State College Press, Ames, Iowa. 1946.
40. SNOW, L. M. Development of root hairs. *Bot. Gaz.* 40: 12–48. 1905.
41. Standard Methods for the Examination of Water and Sewage. Amer. Pub. Health Assoc. Ninth Ed. 1946.
42. STEWARD, F. C. Salt accumulation by plants — the roles of growth and metabolism. *Trans. Faraday Soc.* 33: 1006–1016. 1937.
43. ———— STOUT, P. R., and PRESTON, C. The balance sheet of metabolites for potato discs showing the effect of salts and dissolved oxygen on metabolism at 23 degrees C. *Plant Phys.* 15: 409–447. 1940.
44. TAYLOR, D. L. Influence of oxygen tension on respiration, fermentation, and growth in wheat and rice. *Amer. Jour. Bot.* 29: 721–737. 1942.
45. VLAMIS, J., and DAVIS, A. R. Germination, growth, and respiration of rice and barley seedlings at low oxygen pressures. *Plant Phys.* 18: 685–692. 1943.

# The Effect of Various Concentrations of Fluorine Gas on Gladiolus

By ALEX LAURIE, RAYMOND F. HASEK, and WALLACE LAFLEUR, *Ohio State University, Columbus, Ohio*

CONSIDERABLE damage to gladiolus plants has been found when they are field grown near phosphate fertilizer plants in the state of Florida. In an effort to determine the cause of damage, plants of the gladiolus variety Picardy were subjected to atmospheres containing various concentrations of fluorine. This element had been known to cause injury to other types of plants as reported by Miller, Johnson and Allmendinger (1). Exposure of the plants to fluorine containing atmospheres was accomplished by placing them in wooden frame cages each of which measured 30 inches by 30 inches by 30 inches and covered with transparent Lumarith. A 25 milliliter burette was attached in an upright position to one outside vertical edge of each cage. Eight millimeter glass tubing was bent to pass through the wooden frame of the cage immediately below the burette. One end of this tube was flared into a funnel shape and set directly below the delivery end of the burette. The rest of the tube extended into the cage to a point near the center and approximately 2 to 3 inches above the wooden floor. The purpose of this will be explained later. A vertical water pipe entered the cage through a hole situated in the center of the floor. Surmounting the pipe was a Skinner "HU" air humidifying spray nozzle. One entire side of the cage was hinged in such a way as to act as a door for ease in moving and handling the plants.

The initial series of exposures was carried out on corms potted four to a 6-inch, azalea pot on April 10, 1948. The plants were allowed to grow in the greenhouse until treatments were started on May 14, 1948. At this time the plants were 18 to 24 inches high. Pilot tests were first conducted in an effort to find at what concentrations injury might be obtained. Further confirmatory tests were then run to substantiate the first set of results. The entire testing period of these plants took place from May 14, 1948 to June 20, 1948.

It was noted in Florida that damage in the gladiolus fields usually occurred shortly after periods of rain or foggy weather. To simulate these conditions in the cages, at 5 o'clock each afternoon the water was turned on for ½ minute and allowed to pass through the "HU" nozzles in a fine mist so that the interiors of the cages and the plants were covered with a thin film of water. The humidity in the cages was approximately 100 per cent after such treatment. The exposure of the plants to the various concentrations of fluorine in the atmosphere was then carried out.

Calcium fluoride was used as the source of fluorine which was released as a gas generated within the cages. The concentrations of the fluorine in the atmosphere were theoretical as far as the parts per million were concerned but the volume of the gas released from known quantities of calcium fluoride was correlated to the volume of the cages to give the designated values. The values of the concentrations of the fluorine in the atmospheres was based on the expansion of

a gram-molecular weight of the fluorine to occupy 22.4 liters of space. The weight of fluorine ($F_2$) potentially used supplied a volume of the pure gas whose relation to the volume of the cage would be in the proportion of 0.5, 1.0, 5.0, 10.0, 100.0, and 1,000.0 parts per million. The actual weights used to supply the above quantities were 0.6 mg, 1.3 mg, 6.7 mg, 13.4 mg, 133.8 mg, and 1338.0 mg of calcium fluoride respectively to the 27,000 cubic inch capacity of the cages.

The desired amount of calcium fluoride was placed in a 100 ml paraffin-coated glass beaker and mixed intimately with fine sand ($SiO_2$). The beaker and its contents was then placed below the outlet of the glass tube mentioned above. Concentrated sulphuric acid was run from the burette into the beaker by means of the glass tube. An excess of this material was added to insure complete evolution of the fluorine from the calcium fluoride. Any of the following compounds might have been evolved in the reaction depending on the quantity of water present: $SiF_4$, $SiF_3OH+HF$, $SiF_2(OH)_2+2HF$, $SiF(OH)_3+3HF$ or $Si(OH)_4+4HF$. Unfortunately, equipment for the measurement of fluorine in the atmosphere was lacking and exact values in parts per million could not be obtained but known quantities of fluorine were present in any or all of the above mentioned forms. Exposure of the plants to the gas was begun at 5:00 p m and the cages remained closed until 7:30 a m. However, it is quite possible that maximum concentrations of the gas were present for only a short period of time due to the strong reactive powers of fluorine compounds. They were then opened to allow free circulation of air and reduce the possibility of damage to the plants from the heat of the day. Each night was counted as an exposure for purposes of interpreting results.

A check cage was used in which every detail was the same as those containing fluorine in the atmosphere, except no calcium fluoride was placed in the paraffin-coated beaker. Thus, conditions were identical as possible in all cages except for fluorine content of the atmosphere. Any damage to the plants in the treatment cages which did not become evident on plants in the check cage could be assumed to be due to the fluorine compounds in the atmosphere.

## General Symptoms

Small desiccated spots first appeared at or near the tip of the leaf. These at first were grey-green but later turn a yellowish white and eventually brown. Shrivelling usually accompanied the initial symptoms. The sheathes at the base of the leaves also showed symptoms in that they become grey and gradually turned a reddish brown. The severity of the symptoms and the total areas of the leaves that were affected depended upon the concentration of the gas used and the number of times the plants are exposed to each concentration. The initial areas which showed symptoms sometimes enlarged to the point where almost entire leaves became white or brown.

The length of time required for the symptoms to become evident depended upon the concentration of the gas surrounding the plants, provided there were no extreme variations in temperature. There was

little if any further elongation in leaves exposed to the high concentrations of the gas.

When gladiolus plants were exposed to atmosphere containing the theoretical 1000 ppm of fluorine for one, two, or three exposures, all symptoms progressed at about the same rate in the early stages. There was no apparent injury the first day following the initial application, but on the second day the upper one-third of many leaves turned grey-green in color. The tips of the sheathes surrounding the leaf bases became brown and some desiccation was evident in all the affected areas. By the third day, the upper two-thirds of most leaves were greyish-white in color. The entire leaf sheathes on most plants were completely brown by this time. At the end of 4 days, the symptoms were about the same in all three groups; however, when the plants were placed under ordinary growing conditions and allowed to develop, the plants in the single exposure group became taller than the rest. This was due to the elongation of the young leaves which had not emerged at the time the treatments were applied. Apparently repeated exposure to high concentrations of fluorine caused the young leaves to show injurious effects since the two and three exposure group plants showed stunting and a great deal more injury. Injury continued to progress in the extent of leaf area covered, with some of the older leaves becoming completely white and finally turning brown. This was most evident on the plants in the two and three exposure groups.

Plants in the 100 ppm concentration did not show symptoms of injury the first day following the initial treatment. Symptoms were generally the same as those found on plants in the 1000 ppm groups except the extent of injury was confined largely to the upper one-half of both leaves and sheathes. Plants subjected to two or three exposures of fluorine at concentrations of 100 ppm continued to show progressively more damage than those exposed but once. Practically the full extent of injury due to fluorine was evident at the end of 3 days when but a single exposure was made. Injury continued to develop a few days afterward on both the two and three exposure plots.

With 10 ppm of fluorine in the atmosphere, no symptoms were evident until the third day after the initial treatment. Tips of the leaves assumed a grey-green color at this time and eventually these areas became white then yellowish-brown by the end of 10 days. Plants in the single exposure group showed injury only at the tips of the leaves or at most 2 to 3 inches downward from the tips. Injury on plants exposed two or three times to the above concentrations of fluorine was extensive enough to include the upper one-third or one-half of the leaf as the number of exposures increased.

On the third day of nightly-treated plants in the 5 ppm plots there appeared small greyish spots at the very tips of the leaves. Small brown areas appeared at the tips of the leaf sheathes. One to 3 inches of the leaf tips became greyish-brown on the fourth day and the grey spots continued to progress downward as far as half the length of the leaves. Some twisting of the leaves was evident and this may have been due to the unequal distribution of the greyish or desiccated areas along the leaf margins. About the upper third of the leaves on many

plants was greyish brown on the fifth day. Chlorosis appeared in more scattered areas than was the case in plants treated with higher concentrations.

When plants were given only one exposure to the gas and then grown normally the symptoms were much the same as above but in this case there were a great many reddish-brown areas interspersed in the greyish or chlorotic areas. These symptoms were evident after 6 or 7 days.

On plants given nightly treatments of 1 ppm of fluorine, the first symptoms were evident after about 4 days. They appeared as small brown areas at the extreme tips of the leaf sheathes with accompanying greyish-brown areas at the extreme tips of the leaves. There was a slight amount of twisting evident. After the fifth day there was complete browning of the tips with reddish-brown and yellow areas immediately below the affected areas on the leaf blades.

Where the plants were exposed but once to 1 ppm of the gas, there was only a slight amount of greying at the tip of the leaves. This was not very extensive even after 6 days.

Plants exposed to ½ ppm of fluorine in the atmosphere were divided into three groups which were given two, four and six exposures respectively. In the two exposure group, small grey spots on the upper 2 to 5 inches of the leaves became evident on the fourth day after the initial exposure. The spots exhibited progressive bleaching finally becoming white by the end of the eighth day. There was no apparent injury on the leaf sheathes of plants in this group.

On the fourth day after treatment began on the four exposure group, tips of the leaves became grey and showed desiccation. The affected area increased in a downward direction for another inch or two in the following 4 days but no further damage was noted. Plants in the six exposure group showed almost exactly the same symptoms as the four exposure group. In all cases the affected areas were largely confined to the tips and margins of the leaves.

Fig. 1 shows some of the symptoms on the foliage collected from plants exposed to various concentrations of the fluorine gas.

Results of chemical analyses of representative samples taken from leaves of gladiolus plants exposed to the various concentrations of fluorine are shown in Table I. The method used in the determination of fluorine was that described in "Changes" in Official and Tentative Methods of Analysis made at the fifty-eighth annual meeting, October 27, 28, 1943, Section 29, Metals in Foods. Journal of the Association of Official Agricultural Chemists. 27: 90–100. 1944. Also included in the table are the results of analyses of samples taken from gladiolus fields which contained injured plants in Florida. The extent of damage to the plants from which the Florida samples were taken could not be determined accurately since the samples arrived in a dried form; however, close examination of the leaves showed definite areas where some sort of unnatural condition existed.

The categories stated as to the extent of damage are purely arbitrary and were placed in Table I to make the correlation between injury to the plant and fluorine content present simpler. The term slight injury

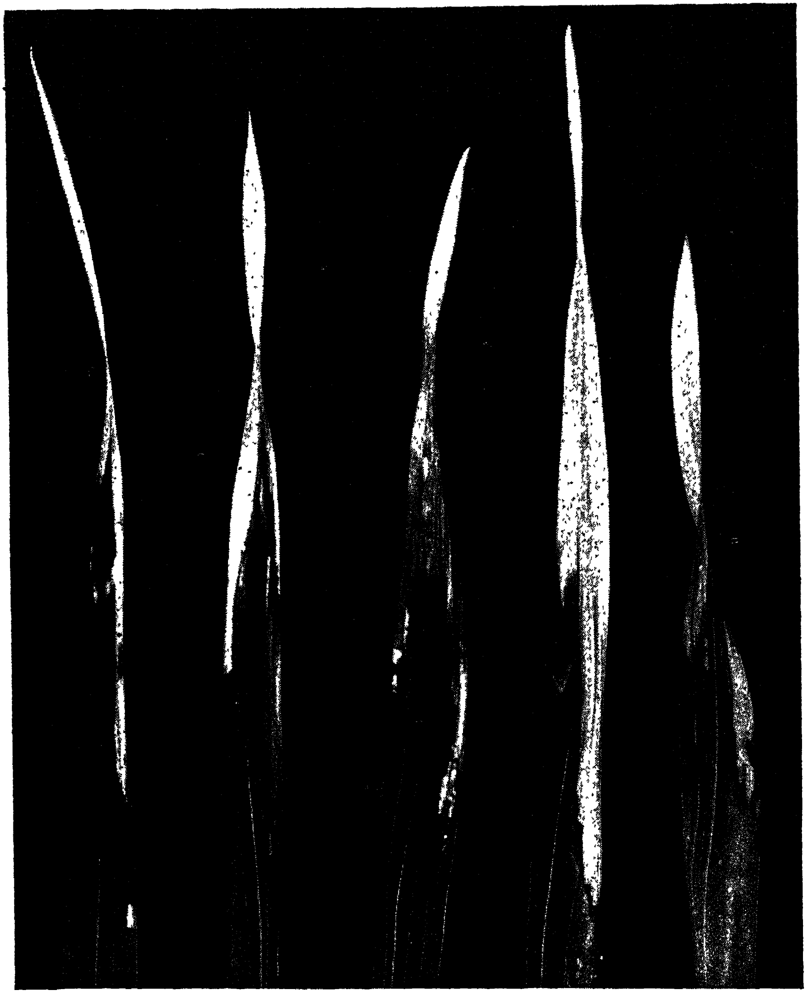

FIG 1. Various degrees of fluorine injury exhibited by the foliage on plants of the gladiolus variety Picardy.

indicates that injury on the foliage was confined to the tips or edges of the leaves. Moderate injury indicates that the damage was confined to the upper one-third of the leaves. Severe injury indicates a condition wherein there was more extensive damage present than in either of the above groups.

The results in Table I may appear at first glance to show inconsistencies between the amount of fluorine absorbed by the plants and the extent of damage to the foliage. There is the possibility, however, that small concentrations of fluorine in the atmosphere for prolonged

TABLE I—FLUORINE ANALYSES EXPRESSED IN PARTS PER MILLION OF THE SAMPLES COLLECTED UNDER CONTROLLED CONDITIONS AT OHIO STATE UNIVERSITY AND ALSO OF SOME SAMPLES FROM INJURED PLANTS IN THE FIELDS OF FLORIDA

| Source | Sample | Extent of Injury | Fluorine Content (Ppm) |
|---|---|---|---|
| O.S.U.......... | Untreated—check plants | None | 1.6 |
| O.S.U.......... | ½ ppm—2 exposures | Moderate | 11.1 |
| O.S.U.......... | ½ ppm—6 exposures | Moderate | 57.5 |
| O.S.U.......... | 1 ppm—1 exposure | Slight | 4.9 |
| O.S.U.......... | 1 ppm—2 exposures | Moderate | 7.3 |
| O.S.U.......... | 5 ppm—1 exposure | Moderate-severe | 11.6 |
| O.S.U.......... | 5 ppm—2 exposures | Severe | 15.2 |
| O.S.U.......... | 10 ppm—1 exposure | Severe | 7.9 |
| O.S.U.......... | 10 ppm—2 exposures | Severe | 86.5 |
| O.S.U.......... | 100 ppm—1 exposure | Severe | 28.5 |
| O.S.U.......... | 1000 ppm—1 exposure | Severe | 311.5 |
| Florida.......... | No. 1 Glad Acres—Suncity | ——— | 19.0 |
| Florida.......... | Picardy Foliage (4–8–48), Piney Point | ——— | 20.8 |
| Florida.......... | No. 2 Picardy, Ft. Meyers | ——— | 10.4 |
| Florida.......... | W.E.K., Sanford | ——— | 85.8 |

periods of time may cause slight or moderate damage to the plants in spite of the fact that relatively large amounts of fluorine were absorbed by the leaves. On the other hand, there is the possibility that relatively high concentrations of fluorine in the atmosphere for short periods of time may result in severe injury to the plants even though relatively small amounts of the element were absorbed by the plants. It might well be that in diagnosing injury to gladiolus plants due to the presence of fluorine gas in the atmosphere both the time and concentration factors would have to be correlated to the extent of injury and chemical analyses of the plants.

In spite of severe injury to the foliage of some of the plants under test, no apparent outward injury could be noted on the roots of any of the plants. The young roots remained white in color at all times. No attempt was made to produce symptoms of fluorine damage on the flowers of the above plants since unsightly foliage in itself was sufficient to render the blooms, and the usual accompanying foliage, unsalable.

It might be mentioned here that on subsequent tests with tomatoes a condition arose which suggested that there may be individual tolerance of some plants toward the presence of fluorine in the atmosphere. At concentrations of 25 and 50 ppm some plants of the variety Marglobe exhibited injury after only one exposure to the fluorine containing atmospheres. The injured plants were removed from the cages after the initial exposure and the undamaged remaining plants were given three additional exposures to the gas. No injury could be noted on these plants even after they had been allowed to grow under normal conditions for 10 days. At concentrations of 100 ppm or more all the tomato plants showed injury after one exposure. At concentrations below 25 ppm no symptoms of injury could be produced.

Apparently the tolerance of the tomato plant toward fluorine in the atmosphere is greater than that of the gladiolus since injury was evident in the latter when only ½ ppm of the element was present in the atmosphere for prolonged periods of time.

## Literature Cited

1. Miller, V. L., Folke, Johnson, and Allmendinger, D. F. Fluorine analysis of Italian prune foliage affected by marginal scorch. *Phytopath.* 38: 1948.

# A Progress Report of Some Rose Root Studies

By JAMES B. SHANKS and ALEX LAURIE, *Ohio State University, Columbus, Ohio*

TWO years ago a study of rose roots was initiated at the Ohio Agricultural Experiment Station, Columbus, Ohio. While the work is still in progress, there is sufficient information on hand to give a preliminary report on the work being done.

Detailed studies of the affects of the several environmental factors upon the roots of many plants have been made but only in a few cases has there been a complete study of the affects of several environmental factors on the roots of a single plant and the subsequent affect upon the top of the plant. The hybrid tea roses grown for greenhouse forcing constitute an important crop plant yet the fundamental practices of rose culture which can be based upon scientific facts are still somewhat limited. Hence a complete and critical study of the environmental factors as they affect the development and functioning of rose roots and the subsequent effect upon top growth is of prime importance. The present study is attempting to include aeration factors, temperature, moisture levels, types of mediums, and fertilizer salts. All plants were grown in the experimental greenhouses at the Ohio State University, Columbus, Ohio.

The work of Cannon (7) was outstanding on aeration. He defined certain critical concentrations of oxygen in the root medium, recognizing that the range in which aeration was effective varied with the different plants and also that this was only true for a given temperature. Such workers as Lawton (12) on corn, Leonard and Pinckard (13) on cotton, Boynton and Compton (3) on apples, peaches, and plums, Nightingale (15) on apples and peaches, Rogers (19) on apples, Childs (8) on apples, and many others have used specific crop plants. Conway (9) drew the general conclusion from literature reviewed that for the majority of plants the $O_2$ concentration must fall to 10 or 11 per cent in the soil atmosphere (or the corresponding concentration in solution) before any injurious effect is produced.

Nightingale (15) and Rogers (19) both included a consideration of root temperature as well as other factors. Other representative works on temperature effects include Allen (1) greenhouse crops; Bailey and Jones (2) blueberry; and Cameron (6) on orange trees.

Brase (4) reported that soil mixtures with peat resulted in increased growth at high moisture levels. Post (17) reported no significant differences in production in roses when watered as the moisture tension of the soil reached 1, 6, or 10 inches of mercury. Haynes (11) working with corn found that vegetative growth was markedly affected by soil moisture content.

Wilde (20) found that flower production of roses was greater where soil contained addition of sharp builders sand. Link and Culbert (14) reported that additions of humus and sand gave better results with roses.

TABLE I—AVERAGE DRY WEIGHTS OF ROSE PLANTS GROWN IN DIFFERENT ROOT MEDIUMS

| Medium | Roots (Grams) | Tops (Grams) | Top:Root Ratio |
|---|---|---|---|
| *Root Systems Not Divided* | | | |
| Loam soil | 14.7 | 103 4 | 7 02 |
| Clay (loose) | 15.8 | 83 4 | 5.28 |
| Clay (packed) | 15.1 | 105.0 | 6 95 |
| Sand | 10.3 | 49.2 | 4.76 |
| Clay plus sand | 14.1 | 59.1 | 4 50 |
| Clay plus manure | 9.0 | 71.9 | 8.00 |
| Clay plus sand plus manure | 13.8 | 86.6 | 6.23 |
| *Root Systems Divided* | | | |
| Clay (loose-packed) | — | — | — |
| ½ clay (packed) | 7.0 | 88 2 | — |
| ½ clay (loose) | 5.8 | — | — |
| *Four Mixtures* | | | |
| ¼ clay | 2.9 | 67.3 | — |
| ¼ clay plus sand | 1 8 | — | — |
| ¼ clay plus manure | 4 5 | — | — |
| ¼ clay plus sand plus manure | 4.1 | — | — |

phate, potassium nitrate, calcium nitrate, sodium phosphate, potassium phosphate, calcium phosphate, potassium chloride, and calcium chloride at the rate of 50 grams per cubic foot of sand. This application was repeated every 6 weeks for the duration of the experiment. The sand at these times was also watered with a solution containing magnesium sulfate, iron sulfate, and manganese sulfate. Water was supplied as in the previous experiment by wicks. The outline of the treatment appears in Table II. The duration of the experiment was 4 months. The roots were carefully washed and the roots and tops dried at 105 degrees C and weighed. Microchemical tests for soluble forms of the four elements (N as nitrate) were made on fresh sections of the young roots.

Table II gives the results of this experiment. As in the previous experiment, there were two plants to a treatment, but both plants gave the same results without any variations. The order of relative importance of the four elements to both root and top growth would appear to be N>P>Ca>K. The relative amounts of the four elements found in the young roots by microchemical examination are also indicated in Table II by "X's" where "X" means "trace" and "XXXXX" means "very abundant". The relative abundance of potassium in nearly all roots indicates that it was translocated rather easily and that possibly for this reason appeared to be less effective than the other three elements.

*Respiration:*—It was felt that the respiration rates of root systems might possibly furnish a valuable index to root activity under certain environmental conditions. Attempts were made in this study to measure root respiration under conditions where the plant was growing actively. Plants were grown in haydite in glazed crocks sealed with grafting wax. Culture solutions were supplied externally. As the culture solution was forced into the crocks the air was trapped in gallon jugs by displacement of water and at the end of irrigation the

TABLE II—AVERAGE DRY WEIGHTS OF ROSE PLANTS WITH VARIOUS FERTILIZER SALTS APPLIED TO SAND AS THE ROOT MEDIUM

| Fertilizer Treatment | Roots (Grams) | Tops (Grams) | Top: Root Ratio | Microchemical Tests on Young Root Tissue | | | |
|---|---|---|---|---|---|---|---|
| | | | | $NO_3$ | P | K | Ca |
| No fertilizer | 10.7 | 8.2 | 0.77 | 0 | 0 | X | XX |
| Complete | 10.3 | 49.2 | 4.70 | XXXX | X | XXXX | 0 |
| *Divided Root Systems* | | | | | | | |
| Complete—none | — | — | — | — | — | — | — |
| 2/4 complete | 5.5 | 20 6 | 2.8 | XX | XXX | XXX | 0 |
| 2/4 none | 4.7 | — | — | 0 | XX | XXX | 0 |
| *Nitrogen Series* | | | | | | | |
| 1/4 $NaNO_3$ | 1.8 | 42 8 | 3.62 | XXXX | 0 | XXXX | 0 |
| 1/4 $NH_4H_2PO_4$ | 4.8 | — | — | XXXXX | XXXX | XXXX | 0 |
| 1/4 $KNO_3$ | 2.2 | — | — | XXXXX | X | XXXXX | 0 |
| 1/4 $Ca(NO_3)_2$ | 2.7 | — | — | XXXX | 0 | XXXX | X |
| *Phosphorus Series* | | | | | | | |
| 1/4 $NaH_2PO_4$ | 0.8 | 27.3 | 3.00 | XX | XXX | XX | 0 |
| 1/4 $NH_4H_2PO_4$ | 4 3 | — | — | XXX | XX | XXXX | 0 |
| 1/4 $KH_2PO_4$ | 2.2 | — | — | XX | XXXXX | XXXX | 0 |
| 1/4 $Ca(H_2PO_4)_2$ | 1.6 | — | — | 0 | XXXXX | XXXX | 0 |
| *Potassium Series* | | | | | | | |
| 1/4 KCl | 1.7 | 12.3 | 1.30 | XX | 0 | XXXXX | 0 |
| 1/4 $KNO_3$ | 2.3 | — | — | XXXX | X | XXXXX | 0 |
| 1/4 $KH_2PO_4$ | 2.6 | — | — | XX | XXXXX | XXXXX | X |
| 1/4 KCl + $CaCl_2$ | 2.6 | — | — | 0 | 0 | XXX | 0 |
| *Calcium Series* | | | | | | | |
| 1/4 $CaCl_2$ | 1.9 | 20.5 | 2.00 | 0 | X | XXX | XXX |
| 1/4 $Ca(NO_3)_2$ | 2.7 | — | — | XXX | X | XXXX | XX |
| 1/4 $Ca(H_2PO_4)_2$ | 4.2 | — | — | X | XX | XXXX | XX |
| 1/4 $CaCl_2$ + KCl | 1.5 | — | — | 0 | X | XXX | X |

same air was drawn back around the roots. Samples of air were analyzed periodically for percentages of oxygen and carbon dioxide and the air around the roots was replaced with fresh air when the oxygen supply became seriously depleted. Unfortunately, however, check crocks which were sealed, but without a plant in them showed almost as much oxygen depletion and carbon dioxide accumulation as where the plants were growing. Additions of 5 ppm of Cu (as sulfate) to the culture solution injured the roses without any appreciable effects upon the respiration other than that of rose roots which was presumably due to micro-organisms. Fermate at the rate of 1 pound per hundred gallons had no effect in reducing this respiration. Although a large amount of data was collected, it means nothing under such conditions and is not presented.

## MOISTURE CONTENT OF THE SOIL

*Procedure*:—The soil used was the top 6 inches of a bluegrass sod which had been composted and put through a soil shredder. A 4–12–4 fertilizer was added at the rate of 100 grams per cubic foot of soil. This was filled 3 inches deep into 10 boxes 2 feet wide and 3½ feet long having either sheet metal or wire mesh bottoms. Fifteen glass fibre wicks were installed in three rows lengthwise of each box and eight plants set so that each was equidistant from four wicks at the

corners of the area each plant occupied. The boxes were then placed over tanks where the water level was maintained at levels varying from 0 to 4½ inches below the soil level with the wicks dipping into the water. The plots were watered once after which all water came through the wick by capillary movement. The surface of the soil was mulched with an inch thick layer of rock-wool insulation material. The moisture content of each plot came to equilibrium and a definite gradient of moisture levels was established although it will not be denied that there were slight variations and fluctuations, especially at the lower moisture levels.

The plants used were Better Times scions grafted on Manetti stock about 3½ months prior to the beginning of the experiment and were very uniform in size at that time. The flower buds were soft pinched on all plants as soon as they reached the size of a pea. The treatment was started on April 2 and the experiment terminated on August 7 at which time the roots were carefully washed and fresh and dry weights of both roots and tops of the plants were recorded.

*Results:*—The amount of moisture in the soil, as found by oven drying, varied from 58.1 per cent moisture for one plot to the two lowest plots which both had 24.2 per cent moisture. The results are shown graphically in Fig. 1. Although the actual data deviate from the curve drawn, it seems obvious that there is a break in the amount of top growth produced in the region of the moisture equivalent of the soil. The best interpretation would seem to be that the curve was fairly level from a point just after the moisture equivalent was reached up to the maximum water holding capacity which in this case was close to 58 per cent.

Since the plants used were grafted and had a large root system at the beginning of the experiment, it is not surprising to find only a slight variation in root growth. In the earlier experiment with moisture content where own root roses were used, the size of the root system was greater in the high moisture plots although the shoot: root ratio still showed a great increase at the high moisture levels.

## Aeration

*Methods:*—Plants for this experiment were rooted cuttings of Better Times roses. They were taken from the cutting bench and placed in 3-gallon glazed crocks 3 weeks before the different treatments were applied, using "FF" grade haydite as the root medium. The haydite was screened to remove smaller particles so that the particles remaining ranged in size from $^1/_{16}$ to $^1/_4$ inches. A culture solution of the following formula was provided using fertilizer grade chemicals:

| | *Millimolar Concentration* |
|---|---|
| Ammonium phosphate | 2.0 |
| Calcium nitrate | 5.0 |
| Potassium nitrate | 6.0 |
| Magnesium sulfate | 3.0 |
| Iron sulfate | 0.72 |
| Manganese sulfate | 0.046 |

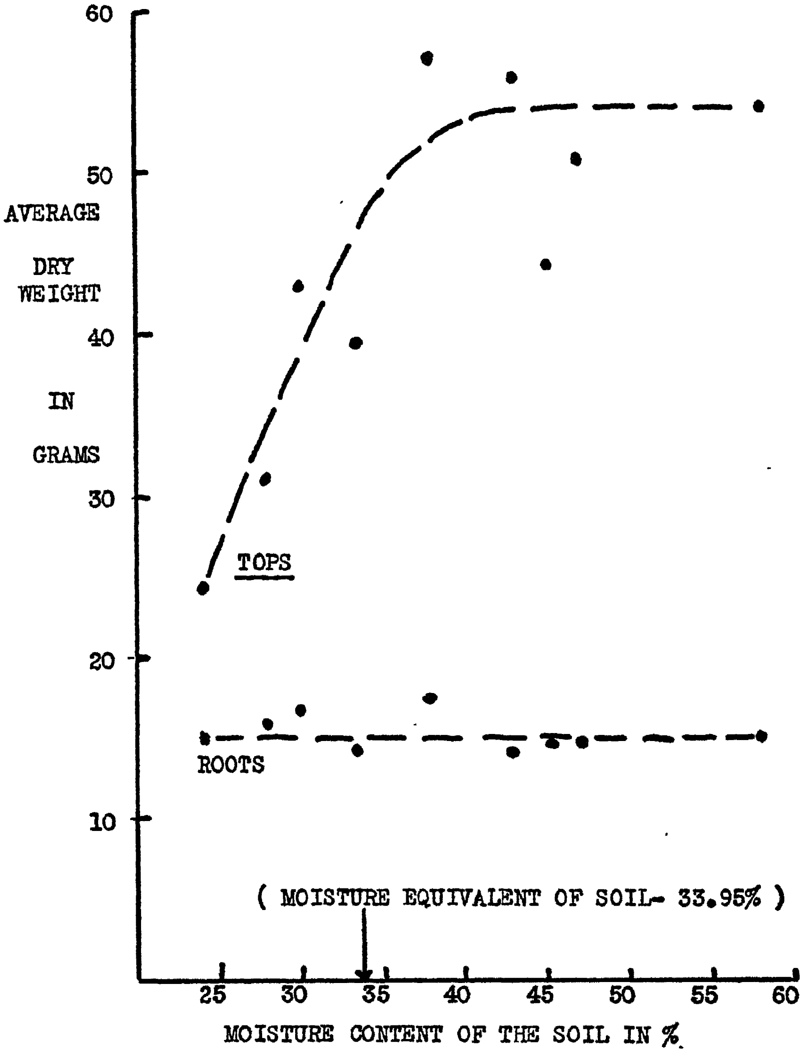


FIG. 1. Growth of roses at different soil moisture levels.

The acidity of the resulting solution was held in the range from 4.2 to 4.5 by additions of phosphoric acid.

Each crock was completely sealed from the atmosphere by a ⅜- to ½-inch layer of grafting wax. The level of the wax was ¾ inch below the lip of the crock and the resulting depression filled with water from time to time to check for leaks which occasionally occurred around the stem. At the time of changing air the pressure built up inside would cause bubbling at the slightest leak. Any leaks were

promptly repaired with another coating of wax. At the bottom of each crock an inlet for nutrient solution was provided and another inlet was provided in the top for entrance of air by sealing an inverted thistle tube into the grafting wax covering.

The nutrient solution for each crock was kept in a gallon jug drilled with a hole in the bottom so that irrigation was accomplished by simply raising and lowering the jug. Air in each crock was forced out by irrigation and new air of the desired mixture flowed in behind the nutrient solution as it drained out of the crock.

The different air mixtures used for the experiment were prepared from cylinders of compressed nitrogen, oxygen, and carbon dioxide. Fifty liter carboys were marked off at intervals to give the desired mixture and then filled with water acidified to a pH of 4.2. The water was then displaced by the required gases keeping the internal pressure equal to atmospheric pressure when bringing to the mark. After several hours the mixture was then forced out of the mixing chambers into the crocks where the plants were growing by displacement with water acidified to pH 4.2 from a barrel placed several feet higher than the mixing chambers.

The air mixtures were calculated to deviate 1 per cent on either side of the required concentration. The mixture for 13 per cent oxygen was actually composed of 14 per cent oxygen and 86 per cent nitrogen and remained there until its composition was approximately 12 per cent oxygen, 86 per cent nitrogen, and 2 per cent carbon dioxide. When the plants were very young, the mixtures were replaced every third day. As more oxygen was used the mixtures were replaced every other day and later every day to keep the concentration of oxygen within the required limits.

Four plants were grown with roots in each of the air mixtures given in Table III. These mixtures were applied on January 21, 1948 and

TABLE III—AVERAGE FRESH AND DRY WEIGHTS OF ROSE PLANTS GROWN WITH VARIOUS AIR MIXTURES AROUND THE ROOTS

| Air Mixture | | | Fresh Weight (Grams) | | Dry Weight (Grams) | |
|---|---|---|---|---|---|---|
| $O_2$ Per Cent | $N_2$ Per Cent | $CO_2$ Per Cent | Roots | Tops | Roots | Tops |
| 20.0 | 75.0 | 5 | 19.5 | 44.9 | 2.31 | 12.56 |
| 20.0 | 70.0 | 10 | 18.2 | 69.2 | 2 23 | 18.27 |
| 20.0 | 65.0 | 15 | 20.0 | 89 8 | 3.01 | 23.22 |
| 20.0 | 60.0 | 20 | 20.3 | 77 0 | 2.69 | 22 06 |
| 1.0 | 99.0 | — | 22.4 | 72.0 | 2.55 | 22.19 |
| 5.0 | 95.0 | — | 15.6 | 38.6 | 1.76 | 11.94 |
| 9.0 | 91.0 | — | 18.2 | 57.6 | 2.27 | 16.81 |
| 13.0 | 87.0 | — | 22.1 | 44.8 | 2.17 | 13.90 |
| 17.0 | 83.0 | — | 15.9 | 32.1 | 1.94 | 9.81 |
| 20.8 | 79.2 | (air) | 23.3 | 77.8 | 3.20 | 24.24 |
| 25.0 | 75.0 | — | 18.9 | 54.7 | 2.29 | 17.31 |
| 29.0 | 71.0 | — | 19.0 | 70.0 | 2.71 | 20.53 |
| 0 | 100.0 | — | (Death) | — | — | — |

supplied continuously until May 15, 1948 when the experiment was discontinued. Plot 13, however, was not started until February 24 and discontinued in 2 weeks because of the death of all four plants. The temperature of the experiment was 60 degrees F at night, 65 degrees F on cloudy days, and 70 degrees F on sunny days. The crocks them-

selves were enclosed by a wooden frame and covered by rock-wool insulation to prevent heating by the suns rays. All flower buds were soft pinched when the size of a pea.

At the end of the experiment the two most representative plants from each plot were preserved in 80 per cent alcohol for future chemical analysis and the others oven dried at 105 degrees C and weighed.

*Results:*—Throughout the duration of the experiment the plants as a whole made good growth. There was considerable plant variation but in all plots at least two plants out of the four were as vigorous as any others in any treatment. From 1 to 29 per cent oxygen and from 0 to 20 per cent carbon dioxide the appearance of the tops of the plants did not give any indication of the extremes of gas concentrations around the roots. Where 100 per cent nitrogen was supplied, the young growth of the plants showed wilting in 3 to 4 days and in 7 days the lower leaves became yellow and abscised. Death soon followed this stage.

There were, however, definite visible differences in the roots produced in the different air mixtures. As compared to the roots in atmospheric air, the young roots in high carbon dioxide concentrations appeared much larger in diameter and were very brittle. The young roots produced in 1 per cent oxygen were just as extensive as those in atmospheric air but very much smaller in diameter, more branched, and very white in appearance. Portions of roots from all plots were preserved for future sectioning and mounting to observe structural differences. This work will be reported later.

Table III gives the average fresh and dry weights of roots and tops. The results of chemical analyses of this material will be published at a later date. Another experiment where these same air mixtures will be used but where the roots will be in soil instead of gravel will be carried on in the fall of 1948 as soon as temperatures in the greenhouse can be controlled. There was some indication from the preliminary experiment that the critical oxygen concentration in soil may be different from that in solution or gravel culture.

## Root Temperature

*Method:*—This experiment was carried on in a greenhouse devoted entirely to growing roses and the tops of all plants were exposed to the same environmental conditions. The air temperature of the house was 60 degrees F at night, 65 degrees F on cloudy days, and 70 degrees F on sunny days. Data collected by Orr (16) showed that the average soil temperature in ground beds in this house approximated 62 degrees F. With this as a guide, five different water baths were set up to control root temperatures at 52 degrees F, 57 degrees F, 62 degrees F, 67 degrees F, and 72 degrees F. Each water bath was 7 feet long, 2 feet wide, and 10 inches deep. Temperatures were held to plus or minus ¼ of a degree by thermostats. Heating was done by electric cables and cooling by additions of cold water. The 62 degrees F plot had both heating and cooling units. Two agitators were in each water bath to keep the temperature uniform throughout. The water

baths were covered on top with a 1 inch thickness of rock-wool insulation material.

The plants were grown in soil in 3-gallon glazed crocks immersed up to 1 inch of the top in the water bath. A 4–12–4 fertilizer was added to the soil at the rate of 100 grams per cubic foot. There were eight plants in each treatment. (The remainder of the space was used for respiration studies).

The plants used were rooted cuttings of Better Times roses which were taken from the cutting bench and placed in the crocks on December 1, 1947. The temperature treatments were started January 2, 1948. All flower buds were soft pinched when the size of a pea. The experiment was discontinued on March 22, 1948 at which time the roots were carefully washed, weighed, and three representative plants from each plot were preserved in 80 per cent alcohol for future chemical analysis. Pieces were also preserved for sectioning and mounting for anatomical studies. The remaining five plants were dried at 105 degrees C and weighed again.

*Results:*—The tops of all the plants were vigorous but the growth of the tops where roots were in the 52 degrees F water bath were much slower growing, shorter internodes, and darker green in color than the others. The roots of the plants in this low temperature appeared long, white, large in diameter, and sparsely branched. By contrast, the tops of plants in the 72 degrees F water bath were the tallest and had a tendency to be less branched while the roots, although well branched and fibrous in nature, were not so extensive. They were brown in color, thin and woody as compared with the white succulent roots in the 52 degrees F water bath. These observations agree quite well with the results of Nightingale (15).

The average fresh and dry weights of roots and tops produced are given in Table IV. The results were very consistent. The fresh weight of the roots decreased as the temperature increased and the dry weight was at a maximum at 62 degrees F. The tops of the plant increased steadily as the root temperature rose from 52 to 67 degrees F and then decreased at 72 degrees F both in fresh weight and dry weight. The indication was that while a root temperature of 72 degrees F was detrimental to top growth, a temperature slightly higher than that found in ground beds in the rose house might be beneficial to top growth and that an optimum root temperature probably lies between 62 and 67 degrees F.

TABLE IV—AVERAGE FRESH AND DRY WEIGHTS OF ROSE PLANTS AS AFFECTED BY DIFFERENT ROOT TEMPERATURES

| Root Temperature (Degrees F) | Average Fresh Weight (Grams) | | Average Dry Weight (Grams) | | Top:Root Ratio on Fresh Weight Basis |
|---|---|---|---|---|---|
| | Roots | Tops | Roots | Tops | |
| 52 | 25.64 | 32.29 | 2.98 | 8.94 | 1.26 |
| 57 | 22.95 | 46.11 | 3.29 | 12.13 | 2.00 |
| 62 | 21.52 | 53.67 | 3.63 | 15.25 | 2.50 |
| 67 | 18.07 | 62.13 | 3.13 | 18.78 | 3.44 |
| 72 | 14.13 | 57.23 | 2.94 | 15.11 | 4.05 |

## Respiration of Rose Roots

*Methods:*—Attempts to gain some measure of the respiration of roots under different conditions of oxygen concentration and temperature while the plant remained intact and actively growing failed. The method of measuring respiration by the use of excised roots in a static closed system contains certain limitations as to the practical interpretation of the results obtained due to the deviation from conditions which exist while the plant is growing. The method was used primarily because of its simplicity. Pint size Mason glass jars were used each provided with a rubber stopper having two capillary tubes inserted which in turn were closed by pinch clamps.

Air mixtures were prepared with varying proportions of oxygen, nitrogen, and carbon dioxide as described previously. There were analyzed with a Haldane type gas analyzer. Temperature control was obtained by immersing the jars in the water baths described previously. Approximately 10 grams of roots were washed in distilled water and placed in each jar. The jar was then filled with water at a pH of 4.2 and the stopper placed so that no bubbles remained inside. The water was then replaced by the air mixtures of the desired composition. After a period of time had elapsed, the air in the jar was analyzed again. Since the analysis of any one run of roots required about 3 hours, a sufficiently long respiration period had to be chosen so that slight differences in time would not be significant. For this reason 48 hours was chosen as the time for any one respiration run and the jars were set up over a 3-hour interval in the same order that the final analysis would be made. Switchbacks of the same root were employed. One root would be run at 21 per cent oxygen, then at two different oxygen concentrations, and finally at 21 per cent oxygen again. The values of the repetition were averaged in evaluating the effects of the other two concentrations. Each treatment was run on three or four different roots.

All roots were of the variety Better Times but obtained from two different sources. One set was from plants which had been grown in gravel culture in the temperatures at which they were used for respiration runs. These were small enough that the entire root of the plant could be used and are listed as intact root systems since the top was cut off above the point where the roots emerged from the stem. The other set of roots was from plants which had made a vigorous growth outdoors the preceding summer and had been held in cold storage from November until February and then forced into growth in the greenhouse. The roots were simply packed in moist sphagnum and the tops covered to prevent excess transpiration and held there until white roots started to show which was usually in 2 to 3 weeks' time. These are listed as excised roots since the entire system of roots was divided at the crown into two or three approximately 10-gram portions.

*Results:*—Fig. 2 shows respiration curves for the intact root systems at the temperatures in which they were grown. Particularly in atmospheric air the rates of both carbon dioxide production and oxygen consumption were greater on these plants at 62 and 67 degrees F than at either higher or lower temperatures. This correlates

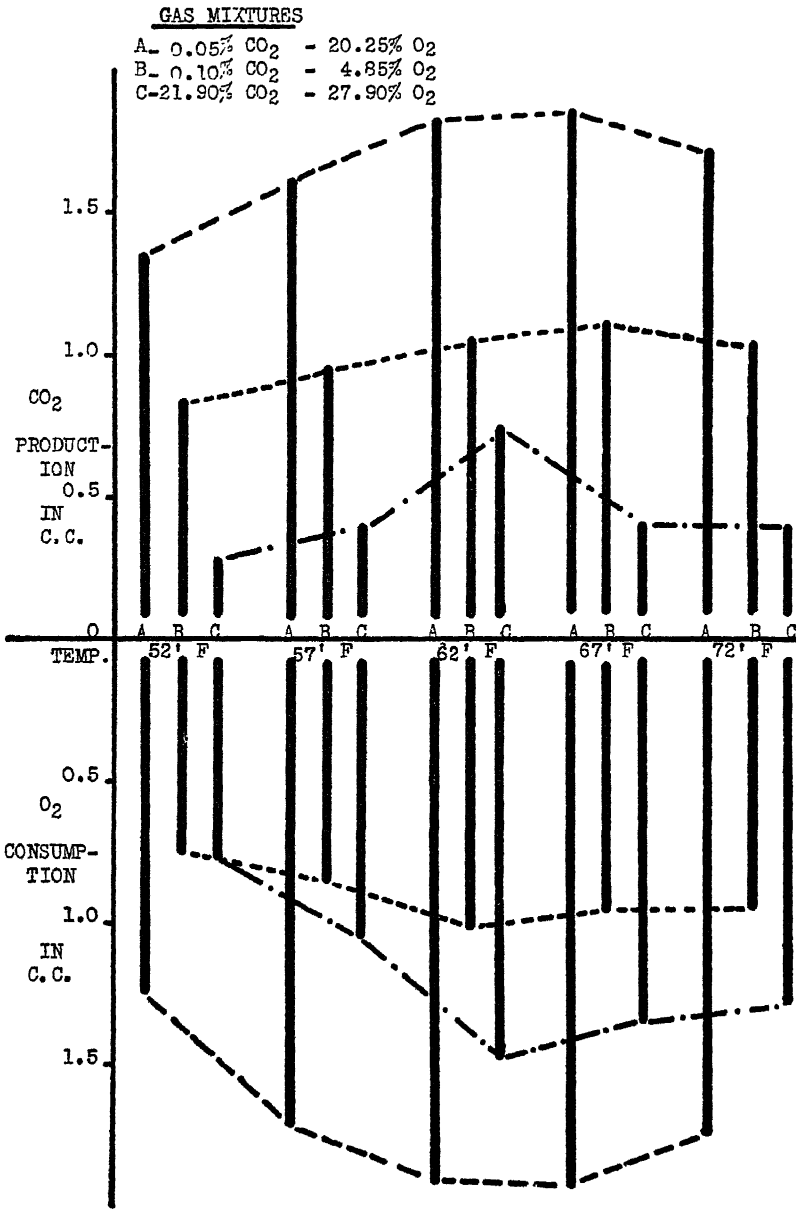


FIG. 2. Respiration of Better Times rose root systems expressed as cc of $CO_2$ produced and $O_2$ consumed per gram fresh weight of roots per 48 hours.

surprisingly well with the production of top growth in these same temperatures.

Fig. 3 shows similar respiration curves for excised roots which had previously had the same temperature treatments. These show the expected increased in respiration as the temperature rises.

Fig. 4 shows curves of carbon dioxide production and oxygen consumption as affected by various concentrations of oxygen and carbon dioxide where the temperature is held at 62 degrees F. The point at

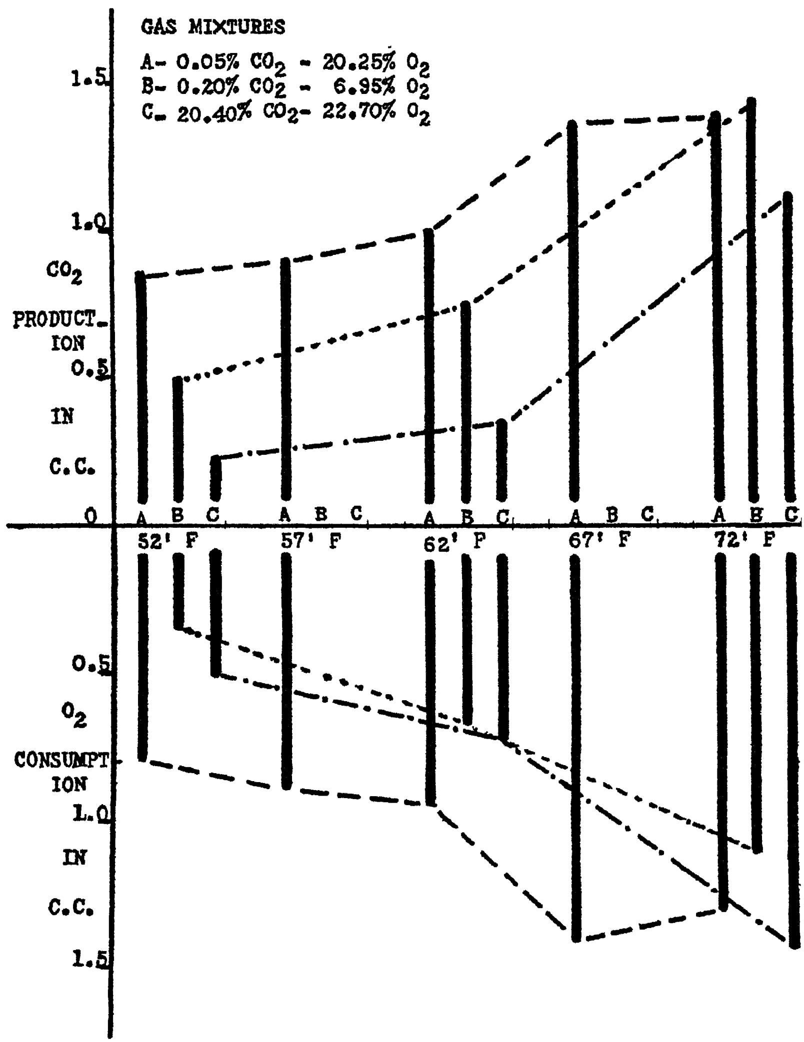


FIG. 3. Respiration of excised roots of Better Times roses expressed as cc of $CO_2$ produced and $O_2$ consumed per gram fresh weight of roots per 48 hours.

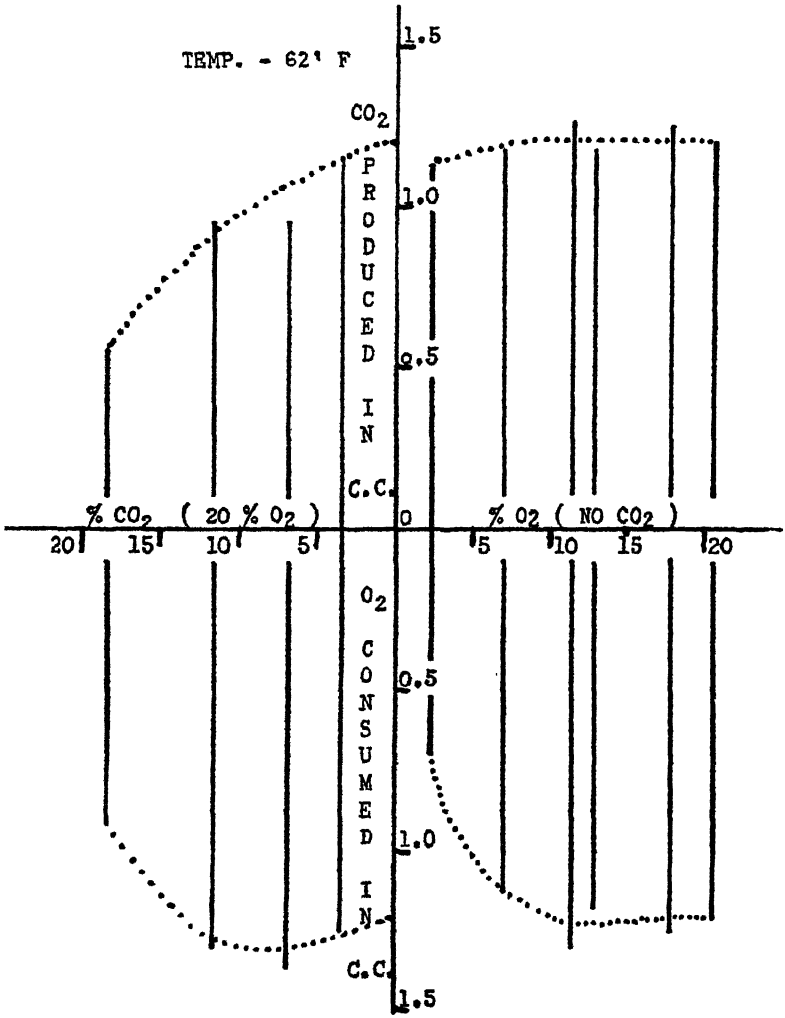


FIG. 4. Respiration of excised roots of Better Times roses expressed as cc of $CO_2$ produced and $O_2$ consumed per gram fresh weight of root per 48 hours.

which respiration is inhibited due to increasing concentrations of carbon dioxide depends upon whether carbon dioxide production or oxygen consumption is used as the index of respiration. The same is true of variations in oxygen concentration. It is evident, however, that oxygen concentration apparently may go to quite low levels and carbon dioxide concentration to relatively high levels before respiration can be said to be repressed to a considerable extent. While these results may not coincide with those in Fig. 3, it is due to the fact that some

of the plants on the temperature series had a respiration period of 5 days instead of 48 hours and the average oxygen concentration was considerably lower than the initial concentration listed.

## Summary

1. Several preliminary experiments of an exploratory nature were carried on and the results used as a basis upon which to set up more complete experiments. The results of these are evaluated only as probable trends.

2. More complete experiments were carried on particularly on the phases of (a) concentrations of oxygen and carbon dioxide for root aeration; (b) temperature of the soil; and (c) moisture content of the soil.

A. In a gravel culture system average carbon dioxide partial pressures as high as 20 per cent and average oxygen partial pressures from 1 to 29 per cent had no significant effect upon the top growth of the rose plants. In high concentrations of carbon dioxide the young roots were larger in diameter and more brittle than in atmospheric air and in 1 per cent oxygen the young roots were extremely small in diameter, white, and highly branched. Pure nitrogen around the roots caused death of the whole plant.

B. The greatest top growth of plants was produced where roots were in a temperature of 67 degrees F. The greatest root growth by fresh weight was at a root temperature of 52 degrees F and by dry weight at a root temperature of 62 degrees F. The top: root ratio increased steadily as the root temperature was increased from 52 to 72 degrees F. The roots at 52 degrees F had young roots which were long, white, very succulent and of large diameter while at 72 degrees F the young roots were brown, woody, and generally fibrous and branched in their appearance.

C. The rate of respiration of roots grown in the above temperatures was greatest at 62 to 67 degrees F. The rate of respiration of roots was reduced by reduced oxygen partial pressures but not to any considerable extent until quite low concentrations of at least 2 per cent were reached. The effect of carbon dioxide on repressing the rate of respiration to any considerable extent was not great until the carbon dioxide concentration was above 15 per cent.

D. The amount of top growth produced at different soil moisture levels indicated that there was a sharp break in the region at or just above the moisture equivalent of the soil used. Above that point there was little, if any, increase in growth up to the maximum water holding capacity of the soil.

3. Complete discussions of the results are withheld until results of chemical analyses, anatomical examinations, and further experiments on some phases, particularly aeration, are obtained. These will be reported at a later date.

## Literature Cited

1. Allen, R. C. The effect of soil temperature on the growth and flowering of certain greenhouse crops. *Proc. Amer. Soc. Hort. Sci.* 32: 635–637. 1934.

2. BAILEY, J. S., and JONES, L. H. The effect of soil temperature on the growth of cultivated blueberry bushes. *Proc. Amer. Soc. Hort. Sci.* 38: 462–464. 1941.
3. BOYNTON, D., and COMPTON, O. C. Effect of oxygen pressure in aerated nutrient solution on production of new roots and on growth of roots and tops of fruit trees. *Proc. Amer. Soc. Hort. Sci.* 42: 53–58. 1943.
4. BRASE, K. D. Root growth and flower production of roses in soil and soil-peat mixtures of varying moisture contents. *Proc. Amer. Soc. Hort. Sci.* 37: 963–966. 1939.
5. BREAZEALE, J. F., and MCGEORGE, W. T. Studies on soil structure: some nitrogen transformation in puddled soils. *Ariz. Agr. Exp. Sta. Bul.* 69. 1937.
6. CAMERON, S. H. The influence of soil temperature on the rate of transpiration of young orange trees. *Proc. Amer. Soc. Hort. Sci.* 38: 75–79. 1941.
7. CANNON, W. A. Physiological features of roots with especial reference to the relations of roots to the aeration of the soil. *Carnegie Inst. of Washington Publ.* 368: 1–168. 1925.
8. CHILDS, W. H. Photosynthesis, transpiration, and growth of apple trees as influenced by various concentrations of oxygen and carbon dioxide in the soil atmosphere. *Cornell Univ. Abstracts of Theses* pp. 431–33. 1940.
9. CONWAY, VERONA M. Aeration and plant growth in wet soils. *Bot. Rev.* 6: 149–163. 1940.
10. DE, KUMAR PRAN, and SARKAR, SACHINDRA, NATH. Transformation of nitrate in water-logged soils. *Soil Sci.* 42: 143–155. 1936.
11. HAYNES, J. L. The effect of availability of soil moisture upon vegetation growth and water use in corn. *Jour. Amer. Soc. Agron.* 40: 385–395. 1948.
12. LAWTON, K. The influence of soil aeration on the growth and absorption of nutrients by corn plants. *Proc. Soil Sci. Soc. Amer.* 10: 263–268. 1946.
13. LEONARD, O. A., and PINCKARD, J. A. Effect of various oxygen and carbon dioxide concentrations on cotton root development. *Plant Phys.* 21: 18–36. 1946.
14. LINK, CONRAD B., and CULBERT, J. R. Effect of soil mixtures on production and growth of briarcliff roses. *Proc. Amer. Soc. Hort. Sci.* 42: 635–637. 1943.
15. NIGHTINGALE, G. T. Effects of temperature on growth, anatomy, and metabolism of apple and peach roots. *Bot. Gaz.* 96: 581–639. 1935.
16. ORR, HENRY P. Studies on the effect of the temperature of water and methods of application of water on the growth of the rose plant. A thesis presented for the degree of Master of Science, Ohio State University. 1947.
17. POST, KENNETH, and SEELEY, JOHN G. The constant water level method of watering roses. *Proc. Amer. Soc. Hort. Sci.* 49: 441–443. 1947.
18. ROBINSON, O. W. Some chemical phases of submerged soil conditions. *Soil Sci.* 30: 197–217. 1930.
19. ROGERS, W. S. Root Studies VIII. Apple root growth in relation to root-stock, soil, seasonal and climatic factors. *Jour. Pom. and Hort. Sci.* 17: No. 2. June 1939.
20. WILDE, E. I. The effect of different soil media on the production of flowers of Better Times roses. *Proc. Amer. Soc. Hort. Sci.* 37: 942–944. 1939.

# The Effect of Warm Water Applications to Greenhouse Roses

By Peter B. Pfahl, Henry P. Orr, and Alex Laurie, *Ohio Agricultural Experiment Station, Wooster, Ohio*

The value of warming water prior to its application to plants has been studied by many. Beneficial results on growth and flowering have been reported on such crops as gladioli, poinsettias, outdoor roses, and gardenias. General recommendations for rose growers usually included the heating of water prior to application. To test the accuracy and need for such recommendations, experiments were conducted for two years to find the effect of warm water treatments on the growth and production of greenhouse roses. The work reported in this paper is a summary of the tests carried on at Ohio State University, Columbus, Ohio during 1947 and 1948.

## Procedure

Better Times, started-eye, rose plants were grown in soil in a V-bottom ground bench, and a flat bottom raised bench. Each soil bench was divided into 10 equal sections. A Pick instantaneous heater, manufactured by the Pick Manufacturing Company, West Bend, Wisconsin, was used to heat the water applied to the soil. The Pick heater operates by controlled injections of live steam into cold water until the desired temperature is reached.

In the winter of 1946–47, two plots in each soil bench were watered with the cold water as it came from the water main, averaging 44 degrees F for the three winter months recorded. The remaining plots were watered with 75 and 90 degrees F water with four replications of each treatment.

In one bench of roses grown in gravel culture with B grade haydite as a medium, the solution was heated to 90 degrees F. A second bench of haydite was used as a check with solution which averaged 64.0 degrees F. However, within 17 days, there was such an inhibiting effect from the 90 degrees F solution temperature on the growth of the plants that the temperature was reduced to 80 degrees F, and after 2 months the experiment was discontinued.

Thermocouples, made from twisted Leeds and Northrup 30–D–2 copper constantan wire, were buried 3 inches below the soil surface in each plot. Temperatures were recorded every hour of the day from 8 a m to 5 p m on the days when no watering was required. On the days the plots were watered, soil temperatures were recorded 15 minutes both before and after the applications of water; and every 2 hours thereafter for 8 hours.

To check the results of the first year, a similar experiment was set-up during the winter of 1947–48. Four plots in each bench were watered with the tap water which averaged 46 degrees F. Three plots were watered with water heated to 70 degrees F, and three plots with water heated to 80 degrees F. Using the same method as the previous year, temperatures of the soil were recorded every 2 hours on

the days no watering was required. When the plots were watered, temperatures were recorded 15 minutes both before and after the application, and every hour thereafter for 8 hours. The experiments were only conducted from November 1, 1947 to March 1, 1948.

TABLE I—AVERAGE HOURLY TEMPERATURE OF THE SOIL FOR THREE MONTHS (RECORDS MADE ON DAYS NO WATERING REQUIRED)

| | Time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 AM | 9 AM | 10 AM | 11 AM | 12 M | 1 PM | 2 PM | 3 PM | 4 PM | 5 PM |
| Temperature . . . . | 61.6* | 64.0 | 63.8 | 64.4 | 65.6 | 65.1 | 66.7 | 67.1 | 66.4 | 66.0 |

*All temperatures given in degrees Fahrenheit.

TABLE II—COMPARATIVE EFFECTS OF VARIOUS TEMPERATURES OF WATER ON THE TEMPERATURE OF THE SOIL (NOVEMBER 1, 1947 TO MARCH 1, 1948)

| Treatment | Hours | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15 Min Before | 15 Min After | 1 Hr After | 2 Hrs After | 3 Hrs After | 4 Hrs After | 5 Hrs After | 6 Hrs After | 7 Hrs After | 8 Hrs After |
| Check**. . . . . . . . . . | 65.6* | 58 5 | 60.9 | 63.0 | 63.8 | 65.1 | 65.4 | 65.8 | 66.0 | 66.4 |
| 70 degrees F. . . . . . . | 65.1 | 69 7 | 68 5 | 68.1 | 67.9 | 67.8 | 67.5 | 66.8 | 66.3 | 66.3 |
| 80 degrees F. . . . . | 64.9 | 72.9 | 71.0 | 69 9 | 69.2 | 68.8 | 68.5 | 67.5 | 67.4 | 66.7 |

*All temperatures given in degrees Fahrenheit.
**Check water averaged 46.0 degrees F.

TABLE III—COMPARATIVE EFFECTS OF WATERING TREATMENTS ON THE TEMPERATURE OF HAYDITE FOR 28 DAYS

| Treatment | Time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 AM | 9 AM | 10 AM | 11 AM | 12 M | 1 PM | 2 PM | 3 PM | 4 PM | 5 PM | 6 PM |
| Solution | | | | | | | | | | | |
| Check. . . . . . | 60.1* | 63.1 | 65.3 | 65.3 | 67.0 | 68.5 | 68.1 | 67.8 | 66.7 | 67.5 | 60.1 |
| 80 degrees F | 63.5 | 65.9 | 73.2 | 72.4 | 70.9 | 73.4 | 73.5 | 74.2 | 76.7 | 74.3 | 67.9 |

*All temperatures given in degrees Fahrenheit.

TABLE IV—THE EFFECT OF WARM WATER ON ROSE PRODUCTION FROM JULY 1, 1947 TO JULY 1, 1948

| Treatment | Flowers Per Plant | Salable Flowers Per Plant | Mean Stem Length |
|---|---|---|---|
| *Ground Bench—Soil* | | | |
| Check. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.46 | 22.43 | 19.08 |
| 70 degrees F. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.32 | 22.29 | 19.08 |
| 80 degrees F. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.03 | 21.98 | 18.65 |
| *Raised Bench—Soil* | | | |
| Check. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.43 | 22.42 | 19.04 |
| 70 degrees F. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.39 | 22.37 | 19.16 |
| 80 degrees F. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 22.13 | 22.12 | 18.87 |
| *Gravel Culture* | | | |
| Check. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 19.58 | 19.56 | 16.44 |
| 90 degrees F and later 80 degrees F. . . . . . . . . . . | 15.94 | 15.93 | 17.85 |

## Discussion of Results

Table I shows that the temperature of the soil remained approximately the same as that of the greenhouse air which was kept at a night temperature of 60 degrees F on cloudy days and 70 degrees F on sunny days. The soil temperature rose from 61.6 degrees at 8 a m to 67.1 degrees F at 3 p m, and declined after 3 p m.

Table II shows that the effect of either warm or cold water did not last longer than 8 hours in the soil. The check water of 46 degrees F average, lowered the soil temperature 7 degrees about 15 minutes after application, and then the soil temperature began to rise. The 70 degrees F water raised the soil temperature approximately 4½ degrees, and the 80 degrees F water raised it 8 degrees. The soil temperatures started to decline within 1 hour, and in 8 hours they were similar to those of the check plots. Similar results were obtained from the raised bench except all the temperatures averaged about 1 degree higher than the ground bench.

The temperature of the haydite fluctuated rapidly with temperature changes in the greenhouse. Table III shows that with 80 degrees F solution, pumped twice a day, the medium average temperature was 71.4 degrees F as compared to 65.4 degrees F in the bench pumped with a solution averaging 64.0 degrees F. A 90 degrees F solution used for 17 days inhibited the breaking of the buds of the young plants. During the following 2 months the initial inhibiting effects of the 90 degrees F solution became less noticeable with the use of the 80 degrees F solution.

The number of bottom breaks were counted both years at the end of the growing season, but the results were not significant. There was a slightly higher percentage in all of the check plots.

Flower production records for 1 year are shown in Table IV, which includes 4 months prior to the warm water treatments, 4 months during the treatments, and 4 months following. In both benches of soil the check plots gave the greatest production; and the warm water plots the lowest. The check haydite bench gave better production than that in which the solution had been heated to 90 degrees F and lowered to 80 degrees F. The results of the second year substantiated the results from the first year.

## Summary

These results for two separate years indicate that it would not be commercially practical to heat the water or the soil for growing greenhouse roses. Warm water applied to the soil did not significantly increase the growth, production, quality of the flowers, nor bottom breaks produced by the plants. Inhibiting effects were observed after a 17 day use of 90 degrees F solution on rose plants grown in haydite.

# Studies on Propagation of Greenhouse Roses by Cuttings

By ALEX LAURIE and EUGENE STILLINGS, *Ohio Agricultural Experiment Station, Wooster, Ohio*

PROPAGATION of roses by cuttings is an old practice, yet little specific information is really available. Conflicting ideas and results of former investigations have led the authors to re-examine the situation and attempt to clarify the old practices and establish new standards. To do this the cooperation of the Joseph H. Hill Company of Richmond, Indiana was secured and a fund was set up and cutting material furnished on a large scale by this company.

The studies concerned humidity, bottom heat, the use of growth substances, the most suitable rooting mediums, slitting and scoring the cuttings, precooling, the use of artificial light, temperature variations in the air and in the medium, methods of watering, age of tissue, types and position of cut and soaking treatments.

In all cases several replications of each test were run and many of the tests were continued throughout the entire year, each being repeated at least six times during the season. The first cuttings were made in October 1946 and every month thereafter until August 1947. The tests were again continued in 1948.

The equipment was automatic in the case of humidity through the use of Binks humidifying nozzles controlled by Minneapolis-Honeywell humidistats. Bottom heat was maintained by means of electric resistance cables thermostatically controlled. Artificial light was applied in a specially constructed "basement greenhouse" where the temperature remained constant through insulation, humidity was regulated automatically, watering was done by the constant level method. The only variant was light, which was supplied by industrial type fluorescent tubes and reflectors with built-in transformers. The lamps were hung 6 inches above the cuttings and the intensities produced were: gold — 100 foot candles, white — 110 foot candles, red — 20 foot candles, and daylight — 130 foot candles. All propagation benches were raised, shallow V-bottom, watertight steel tanks, 6 inches deep. The varieties used were Better Times and Golden Rapture. All figures given are averages of several tests.

## HUMIDITY

To determine the effect of different percentages of relative humidity on the rooting response, three ranges of humidity were established — low (50 to 60 per cent), medium (70 per cent), and high (85 to 90 per cent).

The data contained in Table I show that a high humidity was favorable for rooting Golden Rapture cuttings in the summer, and that a relative humidity of 70 per cent was superior to a higher or lower concentration of air moisture for Better Times in the winter months.

## BOTTOM HEAT

It has long been felt that heat below a rooting medium was essential for favorable rooting response during the autumn, winter, and spring

TABLE I—THE ROOTING RESPONSE OF CUTTINGS OF BETTER TIMES AND GOLDEN RAPTURE ROSES IN ATMOSPERES OF VARIED RELATIVE HUMIDITIES

| | High Humidity (85 to 90 Per Cent) | Medium Humidity (70 Per Cent) | Low Humidity (50 to 60 Per Cent) |
|---|---|---|---|
| | *Golden Rapture* | | |
| Jul–Aug | 63 | 50 | 60 |
| Dec–Jan | 34 | 32 | 17 |
| | *Better Times* | | |
| Dec–Jan. | 41 | 53 | 35 |

months of the year. To determine the most satisfactory bottom temperatures, similar benches with the same mediums were equipped with bottom heat of different temperatures by means of a thermostatically controlled electric cable.

The data from several tests averaged in Table II show no significant difference in Golden Rapture between 70 and 80 degrees F and a significant difference when 60 to 66 degrees F temperature is used. In Better Times there is no significant difference in any temperatures during the September-October rooting period and quite a significant effect of 80 degrees F temperature during late fall.

TABLE II—THE EFFECT OF VARIED MEDIUM TEMPERATURES ON ROOTING RESPONSE OF CUTTINGS OF BETTER TIMES AND GOLDEN RAPTURE ROSES

| | High Bottom Heat (80 Degrees F) | Medium Bottom Heat (70 Degrees F) | No Bottom Heat (60 to 66 Degrees F) |
|---|---|---|---|
| | *Golden Rapture* | | |
| Sep–Oct | 60 | 58 | 37 |
| | *Better Times* | | |
| Sep–Oct | 47 | 56 | 51 |
| Oct–Nov | 13 | 48 | 45 |

## GROWTH SUBSTANCES

Some commercial propagators of roses have practiced dipping the basal end of the cutting in a solution of indolebutyric acid and again in Fermate dust to stimulate root production. The Fermate dip was used as a fungicidal treatment, although some have ascribed stimulative action to it as well.

TABLE III—ROOTING RESPONSE OF SOFTWOOD CUTTINGS OF GOLDEN RAPTURE AND BETTER TIMES ROSES AS AFFECTED BY TREATMENT WITH INDOLEBUTYRIC ACID AND FERMATE

| | Check | Dipped IB | Dipped IB and Fermate |
|---|---|---|---|
| | *Golden Rapture* | | |
| Jul–Aug | 34 | 62 | 63 |
| Jul–Aug | 43 | 43 | — |
| Sep–Oct | 49 | 73 | — |
| Sep–Oct | — | 50 | 51 |
| | *Better Times* | | |
| Sep–Oct | 52 | 57 | — |

The data are indicative that treatment with either indolebutyric acid alone or idolebutyric and Fermate was beneficial, and that Fermate did not affect the rooting percentages of Golden Rapture cuttings. This effect is contrary to the findings of Houston and Chadwick working with Better Times, although there may be a varietal difference involved.

A second experiment with growth substances was designed to determine the rooting response to treatment with the commercial growth promoting substances which are on the market at the present time.

TABLE IV—ROOTING RESPONSE OF SOFTWOOD CUTTINGS OF BETTER TIMES AND GOLDEN RAPTURE AS AFFECTED BY TREATMENT WITH COMMERCIAL GROWTH PROMOTING SUBSTANCES

| | Check | IB | Dow Quick Root No. 1 | Dow Quick Root No. 2 | Rootone | Hormodin No. 1 | Hormodin No. 2 |
|---|---|---|---|---|---|---|---|
| | | | | *Better Times* | | | |
| Oct–Nov | 42 | 24 | 39 | 32 | 40 | 36 | 31 |
| Nov–Dec | 79 | 81 | 76 | 66 | 90 | 89 | 42 |
| | | | | *Golden Rapture* | | | |
| Oct–Nov | 40 | 55 | 63 | 58 | 54 | 55 | 65 |

All the growth substances used had an inhibiting effect on rooting of Better Times cuttings the first time they were tried. The contradictory effect of indolebutyric acid in this test as compared with the previous test is inexplicable.

The second series of Better Times shows that only three substances, indolebutyric acid, Rootone, and Hormodin No. 1 produced a favorable effect on cuttings.

It is possible that previous treatment of the plant material and resulting condition of the stems other than age may influence the reaction of cuttings treated with growth substances.

The cuttings of Golden Rapture responded favorably to all treatments. Such a reaction as compared to the other variety could be ascribed to a varietal difference.

## ROOTING MEDIUMS

Different propagators of roses use different mediums, and each usually feels his is superior to all others. A number of different mediums were tried for both Golden Rapture and Better Times softwood cuttings at various intervals during the year.

The first experiment, in which seven mediums were used, showed that certain materials were more suitable than others. As a consequence, all but three of the mediums were eliminated for the further study. Of the three retained, No. 7 silica sand, No. 2 vermiculite, and bank sand, the third proved unsatisfactory because of the type of roots produced in that medium. They were very thick, clubby, and brittle, and a majority of them were severed when the rooted cutting was pulled. The procedure for removing them without loss was too time consuming for practical operation.

TABLE V—PERCENTAGES OF ROOTED CUTTINGS OF GOLDEN RAPTURE AND BETTER TIMES ROSES OBTAINED IN DIFFERENT MEDIUMS

| | No. 5 (2–3 mm) Silica Sand | No. 7 (1–2 mm) Silica Sand | No. 3 (3–4 mm) Silica Sand | No. 1 (¼–⅜ Ins) Vermiculite | No. 2 (⅛–¼ Ins) Vermiculite | Bank Sand | Bank Sand and Peat | Peat |
|---|---|---|---|---|---|---|---|---|
| *Golden Rapture* | | | | | | | | |
| Jun–Jul . | 1 | 11 | 19 | — | 36 | 31 | 20 | 23 |
| Jun–Jul . . | — | 23 | — | — | 72 | — | — | — |
| Jul–Aug . . | — | 56 | — | — | 38 | 50 | — | — |
| Jul–Aug . . | — | 63 | — | — | 51 | 44 | — | — |
| Sep–Oct . | — | 54 | — | — | 55 | — | — | — |
| Dec–Jan . | — | 30 | — | 25 | 20 | — | — | — |
| *Better Times* | | | | | | | | |
| Jun–Jul | 55 | 77 | 61 | — | 75 | 71 | 29 | 15 |
| Jun–Jul . . | — | 86 | — | — | 77 | 54 | — | — |
| Sep–Oct . | — | 54 | — | — | 50 | — | — | — |
| Oct–Nov . | — | 40 | — | 35 | 32 | — | — | — |
| Dec–Jan . | — | 42 | — | 36 | 47 | — | — | — |
| Jan–Feb . | — | 78 | — | 78 | 73 | — | — | — |

The roots produced in a medium of No. 7 silica sand were flexible and easily handled. Number 2 vermiculite always produced more fine, fibrous, and flexible roots than the other mediums, and the cuttings rooted 3 to 6 days earlier than in the other mediums. Only occasionally, however, was the percentage of rooting as great in vermiculite as it was in No. 7 silica sand.

It is felt that rooting mediums would have little effect on the rooting response of most softwood cuttings if the proper moisture-oxygen relation could be maintained within the mediums. This is more easily accomplished in some materials than in others, with the resulting conclusion that certain materials are apparently superior. This is true only because the watering procedure has been correcting applied with some mediums and not with others. There is some significance in the types of roots produced in different mediums, however.

## SLITTING AND SCORING STEMS

An experiment was designed to determine whether or not more exposed meristematic tissue and more physiological activity as a result of wounding at the base of a cutting might stimulate rooting.

TABLE VI—ROOTING RESPONSE OF SOFTWOOD CUTTINGS OF BETTER TIMES AND GOLDEN RAPTURE AS AFFECTED BY WOUNDING THE BASAL END OF THE CUTTING

| | Check | Slit | Scored |
|---|---|---|---|
| *Golden Rapture* | | | |
| Jul–Aug . . . . . . . . . . . . . . . . . . . . . . | 47 | 51 | — |
| Sep–Oct . . . . . . . . . . . . . . . . . . . . . . | 37 | 49 | — |
| Dec–Jan . . . . . . . . . . . . . . . . . . . . . . | 36 | 24 | 24 |
| Dec–Jan . . . . . . . . . . . . . . . . . . . . . . | 54 | 63 | 57 |
| *Better Times* | | | |
| Sep–Oct . . . . . . . . . . . . . . . . . . . . . . | 52 | 56 | — |
| Dec–Jan . . . . . . . . . . . . . . . . . . . . . . | 36 | 50 | 49 |
| Dec–Jan . . . . . . . . . . . . . . . . . . . . . . | 65 | 64 | 63 |
| Jan–Feb . . . . . . . . . . . . . . . . . . . . . . | 67 | — | 73 |

From Table VI it is evident that in nearly every case, wounding the basal end of the stem proved slightly more beneficial than not wounding. This may be because the effect of the wound stimulus was greater than the effect of the air across the cambial layer.

The practice of scoring, which was adopted to eliminate disturbance of the xylem and pith and still effect of wound of the cambium, produced essentially as beneficial an influence as slitting.

## Precooling Cuttings

It is known that the conversion of starch to sugars within plant tissues will occur more rapidly if those tissues are in a cool temperature than if they are in a warm temperature. It is also known that sugars and not starches are concerned in aerobic respiration which furnishes energy for growth.

It was felt that subjecting rose cuttings to a cool temperature, 45 degrees F, previous to sticking in the rooting medium, for a period of 24 hours, would thus be beneficial for root formation and development of a new plant. This procedure was followed and the results are summarized in Table VII.

TABLE VII—Rooting Response of Better Times and Golden Rapture Rose Cuttings as Affected by Precooling

| | Not Cooled | Cooled 45 Degrees F 24 Hours | Cooled 45 Degrees F 48 Hours |
|---|---|---|---|
| | *Golden Rapture* | | |
| Jul–Aug | 48 | 47 | — |
| | *Better Times* | | |
| Jun–Jan (inclusive) | 57 | 72 | 73 |
| Jan–Feb | 70 | 70 | — |

It is apparent that the precooling had no marked effect on cuttings of Golden Rapture. However, it did noticeably affect the rooting percentages of Better Times cuttings. As noted in previous experiments of this study, this difference in reaction might well be attributed to a varietal difference, which actually may be a story of food accumulation.

## Light

Stoutemyer and Close obtained favorable rooting response on cuttings of numerous plants using various fluorescent light colors in an underground propagation house.

Such a propagation structure theoretically should produce better results than the usual greenhouse which is used, in that most of the external factors affecting rooting of cuttings are more easily controlled, that is, temperature, humidity, and light.

The underground propagation house was fitted with lights of four different colors to determine the effect of light color on rooting of rose cuttings. Table VIII contains the results of this study.

That red light produces less favorable rooting response can be seen by examination of the above data. This is in agreement with Stoute-

TABLE VIII—THE EFFECT OF VARIOUS LIGHT COLORS ON THE ROOTING RESPONSE OF GOLDEN RAPTURE AND BETTER TIMES ROSE CUTTINGS

| | Gold Light | Red Light | Daylight Light | White Light |
|---|---|---|---|---|
| | *Golden Rapture* | | | |
| Oct–Nov | 70 | 28 | 63 | 66 |
| Dec–Jan | 61 | 22 | 76 | 72 |
| | *Better Times* | | | |
| Dec–Jan | 62 | 32 | 82 | 67 |
| Jan–Feb | 64 | — | 82 | 76 |

myer and Close. These tests also showed that daylight fluorescent tubes produced slightly better rooting than the other colors in all experiments but one.

The light intensities taken with a Weston light meter directly under the lights and at the top of the cuttings were as follows: gold, 100 foot candles; white, 110 foot candles; red, 20 foot candles; daylight 130 foot candles. There was a noticeable variation in rooting between the plants directly beneath the reflectors and those at the edge of the bench. This is undoubtedly a case of insufficient light intensity, inasmuch as the variance of the sides from the center of the bench was as much as 70 to 80 foot candles.

About 75 per cent of all the cuttings grown under continuous artificial light had produced shoots up to 5 inches long during the same interval for rooting as required in the greenhouse where shoots were seldom produced.

The time required for root production is slightly less under the continuous artificial light than for the same type cuttings in a greenhouse propagation bench during the winter months.

## AIR TEMPERATURE

Propagation of rose cuttings in a 50 degrees F air temperature and 70 degrees F bottom heat has been practiced by a few commercial propagators with excellent results. To determine the rooting response to such temperatures, a propagation bench was installed in one of the greenhouses where those temperatures were maintained.

Two batches of cuttings propagated under these conditions rooted exceptionally well. The experiment was then extended to correlate the rooting response of different air temperatures when a bottom heat of 70 degrees F was maintained. The results of these studies are shown in Table IX.

TABLE IX—THE ROOTING RESPONSE OF BETTER TIMES ROSES AS AFFECTED BY VARIATIONS IN AIR TEMPERATURE

| | 50 Degrees F Air Temperature | 60 Degrees F Air Temperature | 70 Degrees F Air Temperature |
|---|---|---|---|
| | *Better Times* | | |
| Nov–Dec | 78 | — | — |
| Dec–Jan | 89 | — | — |
| Jan–Feb | 85 | 70 | 47 |

The data in the Table IX indicate that an air temperature of 50 degrees F was beneficial for rooting Better Times roses during the winter months. This may be attributed to the rates of respiration of the cuttings in the various air temperatures, the low air temperature being conducive to a low rate of respiration, resulting in sugars available for root formation.

## Watering Methods

Both manual and constant level subirrigation have been advocated and practiced for production of greenhouse flowers. These practices have in many instances been quite successful. Little work of this nature on rose cuttings has been reported, although subirrigation of rose cuttings is being practiced in some commercial ranges.

The procedures used during the course of the studies here were to apply water to cuttings by constant level subirrigation, manual subirrigation, and overhead, the usual way.

TABLE X—Rooting Percentages Obtained from Rose Cuttings by Different Methods of Watering

| | Overhead Watered | Constant Level Subirrigation | Manual Subirrigation |
|---|---|---|---|
| | *Golden Rapture* | | |
| Jun–Jul | 23 | 44 | 28 |
| Nov–Dec | 51 | — | 69 |
| Dec–Jan | — | 36 | 30 |
| Dec–Jan | 47 | 60 | — |
| | *Better Times* | | |
| Jun–Jul | 72 | 75 | 82 |
| Dec–Jan | — | 47 | 42 |
| Dec–Jan | 59 | — | 52 |
| Jan–Feb | 66 | 76 | 84 |
| Jan–Feb | — | 80 | 76 |

With the exception of the second December-January trials of Better Times, subirrigation provided a more favorable rooting response than did overhead watering with both varieties.

## Age of Wood

To determine whether or not the age of the cane had any influence on the response to rooting, two experiments were designed to study this factor.

Similar canes of Better Times were selected and cuttings were made from the bottom of the cane, middle of the cane, and top of the cane. The results are contained in Table XI.

These data are indicative that it is not always a case of the older wood, which usually has a greater starch reserve, rooting more favorably. To be certain of the starch reserve, actual macrochemical studies must be made.

All the cuttings used in this entire study were made only from wood above a pinch or hook. To determine the rooting response to older, harder wood below the pinch or hook, this material was tried. The

TABLE XI—THE EFFECT OF THE AGE OF WOOD ON THE ROOTING RESPONSE OF BETTER TIMES ROSE CUTTINGS

| | Bottom of Cane | Middle of Cane | Top of Cane |
|---|---|---|---|
| | *Better Times* | | |
| Jun-Jul | 76 | 80 | 100 |
| Jul-Aug | 64 | 76 | — |
| Oct-Nov | 64 | 72 | 64 |
| Oct-Nov | 82 | — | 72 |

results of two trials showed that hard wood did not root as readily as did the softer wood.

## TYPE OF CUT

The type of basal cut may be considered as an important factor in the rooting of rose cuttings. Accordingly, an experiment was designed employing a variation from the standard method.

TABLE XII—THE EFFECT OF TYPE OF CUT ON ROOTING OF BETTER TIMES AND GOLDEN RAPTURE ROSE CUTTINGS

| | Slant Cut | Check (Right Angle Cut) |
|---|---|---|
| *Better Times* | | |
| Dec-Jan | 51 | 36 |
| Dec-Jan | 64 | 63 |
| *Golden Rapture* | | |
| Dec-Jan | 61 | 54 |
| Dec-Jan | 29 | 24 |

The above data suggests that in most cases there is little benefit received from making a slanting cut in comparison to a right angle cut.

## PLACE OF CUT

To determine the place on a stem where the basal cut for the cutting should be made to obtain the most favorable rooting response, cuts were made on Better Times canes (a) just above the node, (b) just below the node, (c) ½ inch below the node, and (d) at the middle of the internode. The first, second, and fourth groups were triplicated, the third group run only once.

TABLE XIII—ROOTING RESPONSE OF BETTER TIMES CUTTINGS IN RELATION TO PLACE OF CUT

| | Cut Just Above Node | Cut Just Below Node | Cut ½ Inch Below Node | Cut at Middle of Internode |
|---|---|---|---|---|
| Better Times | 75 | 61 | 60 | 72 |

The data are indicative that making the basal cut above a node or at the middle of the internode may produce a more favorable rooting response than cutting below a node, although they in no way show this conclusively.

## Summary

1. *Humidity:*—A relative humidity of 80 per cent was more favorable for rooting Golden Rapture in the summer than lower humidities. A 70 per cent relative humidity was superior to a higher or lower concentration of air moisture for Better Times in the winter months.

2. *Bottom Heat:*—A bottom heat of 70 degrees F is generally better than a higher or lower medium temperature.

3. *Growth Substances:*—Treatment of the cuttings with either indolebutyric acid alone or indolebutyric acid and Fermate was beneficial and indications were that Fermate did not affect the rooting percentages of Golden Rapture cuttings. The use of commercial growth promoting substances produced favorable results in rooting Golden Rapture cuttings. Only three of the six treatments indicated a better rooting response on Better Times. It is felt that the previous treatment of the stock plants may affect the response to growth substances.

4. *Mediums:*—Number 7 silica sand and No. 1 vermiculite in general produced more roots than other mediums, and roots of a more desirable nature.

5. *Slitting and Scoring:*—Wounding of the basal end of the cutting by slitting or scoring proved slightly more satisfactory than sticking the cuttings unwounded.

6. *Precooling:*—The practice of precooling cuttings of Golden Rapture produced no apparent effect. The rooting percentages of Better Times were increased by this treatment, however.

7. *Rooting Under Fluorescent Lights:*—Red light produced less satisfactory rooting than did white, daylight, or yellow. It was necessary to suspend the reflectors 5 to 6 inches above the cuttings and illuminate the cuttings for 24 hours to obtain a comparable rooting to that of a greenhouse.

8. *Air Temperature:*—With a bottom heat of 70 degrees F, an air temperature of 50 degrees F produced higher rooting percentages than air temperatures of 60 or 70 degrees F.

9. *Method of Watering:*—Subirrigation, either manual or constant level, in general was superior to overhead watering.

10. *Age of Tissue:*—The lower portions of the cane from which Better Times cuttings were taken did not always produce the most desirable rooting response.

11. *Type of Cut:*—There is little benefit received from making a slanting cut in comparison to a right angle cut.

12. *Place of Cut:*—Cutting above a node may produce as satisfactory rooting as cutting below.

# Bottom Break Production of Rose Plants as Influenced by Plot Location in the Greenhouse

By CHARLES W. FISCHER JR. and ANTON M. KOFRANEK,
*Cornell University, Ithaca, N. Y.*

IN a previous paper Kofranek and Fischer (1) reported lack of statistically significant differences in bottom break production of roses as a result of different soil texture and watering treatments. Analysis presented indicated however that bottom breaks varied as to plant location in the greenhouse and time of recording of bottom breaks.

Bottom breaks were tabulated in a manner described from plots already mentioned; a diagram illustrating positions of rows also appears (1).

TABLE I—AVERAGE BOTTOM BREAK PRODUCTION PER PLANT

| Experiment | Rows | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| Watering*—mulch | 0.64 | 0.24 | 0.20 | 0 44 | 0.24 | 0.36 |
| Watering**—soil texture | 0.70 | 0.21 | 0.28 | 0.13 | 0.13 | 0.23 |

*Least significant difference at 5 per cent —0.20 1 per cent—0.26
**Least significant difference at 5 per cent —0.18 1 per cent—0.24

Differences in magnitude of results between the two experiments may be due largely to the differences in varieties and method of propagation used (see methods, 1).

For both experiments, row I has a significantly higher production than all other locations. The data in the watering-soil texture experiment were found to be significant at the 1 per cent level; the watering-mulch experiment at the 1 per cent level, except for row IV which differs only at the 5 per cent level.

A south location in the greenhouse appears most favorable for bottom break production. The effect is essentially lost in rows removed from I, perhaps due to a shading effect. Row I for watering-soil texture experiment gave high production, since there was an empty bench separating treatments. Row IV of watering-mulch experiment showed relatively good production, perhaps due to the fact that a 24 inch aisle separated it from row III.

Breaks were tabulated in such a manner as to include production that occurred only in the 6-month period prior to the counting date. Production figures show a variation with time.

TABLE II—AVERAGE BOTTOM BREAK PRODUCTION PER OBSERVATION PER PLOT†

| | Nov (1947) Count | Jun (1948) Count |
|---|---|---|
| Water*—mulch | 3.74 | 2.46 |
| Water**—soil texture | 2.58 | 0.75 |

*Least significant difference 5 per cent level—1.02 1 per cent level—1.39
**Least significant difference 5 per cent level—0.44 1 per cent level 0.58
†Figures were determined by summing the counts of bottom breaks at one date and dividing by the total number of plots.

Production is significantly higher in the November count over the June count for both experiments. Differences were found significant at the 1 per cent level in the watering-soil texture experiment, and at the 5 per cent level for the watering-mulch experiment. The 6-month period preceding the November count included a time of high light intensity and the long days of the year, whereas a period of low light intensity and short days prevailed prior to the June count.

## Summary

Counts of bottom breaks and analyses of the figures indicate that light may be an important factor in bottom break production of rose plants. It appears that the greater the light, the greater the production of these basal breaks.

The importance of the locations of experimental plots in the greenhouse and the time of year in which data are recorded is shown in this paper. The need for statistical treatment of data is evident.

## Literature Cited

1. Kofranek, Anton M., and Fischer, Charles W. Jr. Bottom break production of rose plants as influenced by methods of watering and by soil texture. *Proc. Amer. Soc. Hort. Sci.* (In press).

# Bottom Break Production of Rose Plants as Influenced by Methods of Watering and by Soil Texture[1]

By Anton M. Kofranek and Charles W. Fischer Jr.,
*Cornell University, Ithaca, N. Y.*

The occurrence of bottom breaks of roses is of commercial importance because the flower production of the plants is greatly increased by such basal growth. Since the development of the automatic method of watering by Post and Seeley (2), a number of investigations have been made showing the effects of automatic watering on the growth of plants. It is the purpose of this paper to report the observations of bottom break production as influenced by the surface and automatic methods of watering and by various soil textures as well.

## Methods

*Watering-Mulch Experiment:*—The counts of bottom breaks were taken from an experiment designed to study the effects of different methods of watering upon the growth and production of salable roses. The watering treatments were as follows: (a) surface watering when the capillary tension of the soil reached 1 inch (4), (b) constant water level (4), (c) automatic injection at 1 inch tension (2, 3). Manure mulched and unmulched plots were used on the three watering treatments except on the automatic injection method which had only a mulched plot (see Table I).

Each plot consisted of 26 budded plants of the variety Better Times which were planted in May 1946. The spacing of the plants was 12 by 12 inches in plots that measured 3 by 9 feet. The five treatments were in a randomized complete block design with two replicates. The soil used in all plots was a composted Genesee silt loam containing one-quarter manure by volume.

*Watering-Soil Texture Experiment:*—This observation was made on an experiment conducted for the purpose of studying the effects of different textures of soil and methods of watering on the growth and production of salable roses. The six treatments consisted of three soil textures with two methods of watering, constant water level (4) and surface watering. Soils of the Dunkirk series consisting of a clay loam, silty loam and sandy loam were used. No organic matter was incorporated into the soil at the time of planting. The pH and nutrients were adjusted and maintained at approximately the same level throughout the experiment. The soils were tested periodically by the Spurway method (6). Each plot consisted of nine own-root roses of the variety Peter's Briarcliff planted in May 1946. The plants were spaced 12 by 12 inches in 3 by 3 foot plots. The plots were randomized within two benches and each treatment was replicated four times.

*Methods Common to Both Experiments:*—The benches in the greenhouse were divided into six rows extending their entire length.

[1]The authors express their appreciation to Dr. Kenneth Post, under whose direction this project was carried out.

This was done to facilitate the analysis of the data as to the row location as well as to the various treatments. Fig. 1 illustrates the relative position of these rows in the benches.

The criteria for a bottom break were chosen to be (a) origin of the shoot no more than 12 inches above the soil level, (b) a cane of green color with leaves present on the entire shoot and (c) no more than three flowers cut from the shoot prior to the count. The counts were

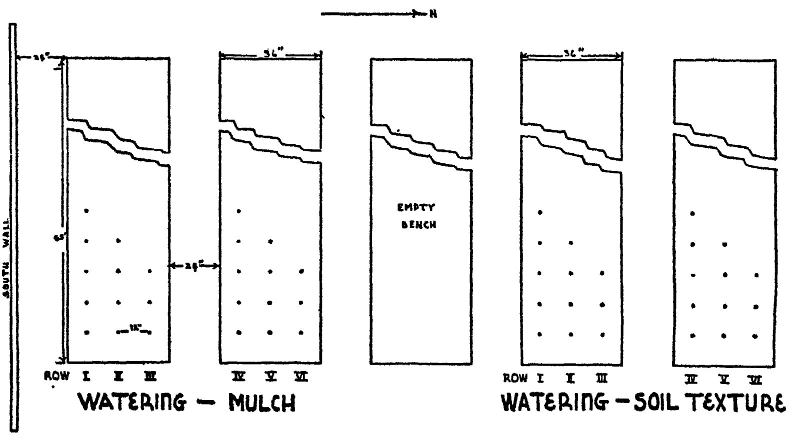


FIG. 1. Arrangment of benches in the greenhouse during experiment.

made November 15, 1947 and June 12, 1948. The latter date was chosen to avoid re-counting the same breaks that were recorded on November 15. This was under the assumption that the maximum time from one cut to the next flower cut was 8 or 9 weeks.

All data were analyzed by analysis of variance as outlined by Snedecor (5). Analysis of the transformed data was conducted and similar results were obtained.

## RESULTS

*Watering-Mulch Experiment:*—Table I is a summary of bottom break production in each of the various treatments and in the different rows in the benches.

A total of 43 bottom breaks were recorded for the automatic watering-manure mulch treatment. This seems high compared to the total of 30 for the surface watering-manure mulch and constant watering-no mulch treatments, but when the data were analyzed, the differences were found to be insignificant. This would indicate that the various watering treatments and mulches had no effect on the producion of bottom breaks. However, it was shown that there were significant differences between the various rows within the benches and also between the dates of recording the data. This is discussed in more detail in a later paper (1).

TABLE I—BOTTOM BREAK PRODUCTION IN WATERING—MULCH EXPERIMENT

| Rows | Date of Count | Treatments: Surface Water Manure Mulch | Constant Water No Mulch | Automatic Water Manure Mulch | Constant Water Manure Mulch | Surface Water No Mulch | Total | | Ave/ Plot | Ave/ Plant |
|---|---|---|---|---|---|---|---|---|---|---|
| I | Nov 15, 1947– | 4 | 6 | 5 | 9 | 10 | 34 | 58 | 5.8 | 0.64 |
| | Jun 12, 1948 | 6 | 6 | 5 | 6 | 1 | 24 | | | |
| II | Nov 15, 1947– | 2 | 2 | 1 | 1 | 3 | 9 | 19 | 1.9 | 0.24 |
| | Jun 12, 1948 | 3 | 1 | 2 | 3 | 1 | 10 | | | |
| III | Nov 15, 1947– | 1 | 3 | 5 | 2 | 2 | 13 | 18 | 1.8 | 0.20 |
| | Jun 12, 1948 | 1 | 0 | 0 | 1 | 3 | 5 | | | |
| IV | Nov 15, 1947– | 2 | 4 | 10 | 6 | 2 | 24 | 40 | 4.0 | 0.44 |
| | Jun 12, 1948 | 1 | 1 | 8 | 1 | 5 | 16 | | | |
| V | Nov 15, 1947– | 2 | 2 | 2 | 1 | 3 | 10 | 19 | 1.9 | 0.24 |
| | Jun 12, 1948 | 0 | 2 | 2 | 3 | 2 | 9 | | | |
| VI | Nov 15, 1947– | 6 | 2 | 2 | 4 | 8 | 22 | 22 | 3.2 | 0.36 |
| | Jun 12, 1948 | 2 | 1 | 1 | 4 | 2 | 10 | | | |
| | Total. . . . . | 30 | 30 | 43 | 41 | 42 | | | | |

*Analysis of Variance*

| Source of Variance | Degrees of Freedom | Mean Square | F |
|---|---|---|---|
| Treatments. . . . . . . . . | 4 | 3.64 | 0.99 |
| Rows . . . . . . . . . . . . | 5 | 25.36 | 6.87** |
| Date of Count. . . . . | 1 | 24.07 | 6.52* |
| Row × Treatments. | 20 | 4.50 | —— |
| Row × Date of Count | 5 | 2.67 | —— |
| Remainder (Error). . | 24 | 3.69 | —— |
| Total. . . . . . . . . . . | 59 | | |

TABLE II—BOTTOM BREAK PRODUCTION IN WATERING—SOIL TEXTURE EXPERIMENT

| Rows | Date of Count | Treatments: Constant Water Sand | Surface Water Sand | Constant Water Silt | Surface Water Silt | Constant Water Clay | Surface Water Clay | Total | | Ave/ Plot | Ave/ Plant |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | Nov 15, 1947– | 8 | 11 | 3 | 8 | 4 | 8 | 42 | 51 | 2.1 | 0.70 |
| | Jun 12, 1948 | 4 | 0 | 3 | 0 | 1 | 1 | 9 | | | |
| II | Nov 15, 1947– | 1 | 2 | 3 | 2 | 2 | 1 | 11 | 15 | 0.63 | 0.21 |
| | Jun 12, 1948 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | | | |
| III | Nov 15, 1947– | 0 | 2 | 1 | 4 | 2 | 6 | 15 | 20 | 0.83 | 0.26 |
| | Jun 12, 1948 | 1 | 0 | 1 | 0 | 1 | 2 | 5 | | | |
| IV | Nov 15, 1947– | 0 | 0 | 1 | 1 | 2 | 0 | 4 | 9 | 0.38 | 0.13 |
| | Jun 12, 1948 | 2 | 1 | 0 | 1 | 0 | 1 | 5 | | | |
| V | Nov 15, 1947– | 1 | 1 | 1 | 3 | 2 | 0 | 8 | 9 | 0.38 | 0.13 |
| | Jun 12, 1948 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | | | |
| VI | Nov 15, 1947– | 3 | 5 | 0 | 1 | 1 | 3 | 13 | 16 | 0.67 | 0.23 |
| | Jun 12, 1948 | 0 | 2 | 0 | 0 | 1 | 0 | 3 | | | |
| | Total. . . . . . . | 20 | 25 | 14 | 21 | 17 | 23 | | 120 | | |

*Analysis of Variance*

| Source of Variance | Degrees of Freedom | Mean Square | F |
|---|---|---|---|
| Treatments. . . . . . . . . . . . | 5 | 0.67 | 0.77 |
| Rows. . . . . . . . . . . . . . . . . | 5 | 10.37 | 11.92** |
| Date of Count. . . . . . . . . . | 1 | 30.25 | 34.77** |
| Replications. . . . . . . . . . . | 1 | 0.69 | —— |
| Rows × Treatments. . . . . | 25 | 0.97 | —— |
| Rows × Date of Count. . . | 5 | 5.52 | —— |
| Remainder (Error) . . . . . . | 101 | 0.87 | —— |
| Total. . . . . . . . . . . . . . . | 143 | | |

This was done to facilitate the analysis of the data as to the row location as well as to the various treatments. Fig. 1 illustrates the relative position of these rows in the benches.

The criteria for a bottom break were chosen to be (a) origin of the shoot no more than 12 inches above the soil level, (b) a cane of green color with leaves present on the entire shoot and (c) no more than three flowers cut from the shoot prior to the count. The counts were

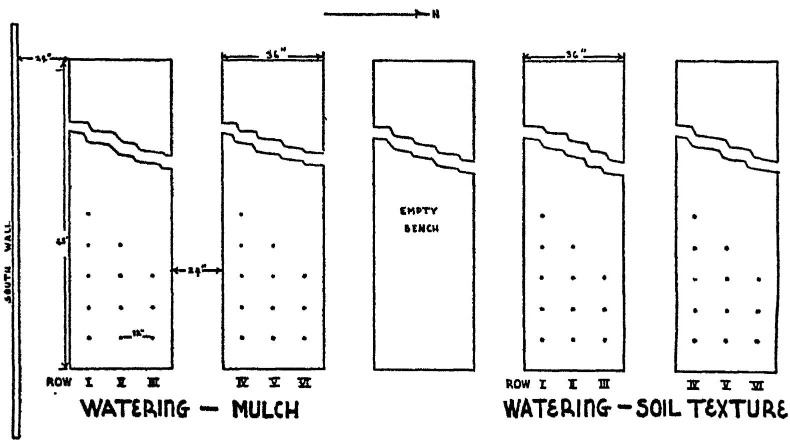


Fig. 1. Arrangment of benches in the greenhouse during experiment.

made November 15, 1947 and June 12, 1948. The latter date was chosen to avoid re-counting the same breaks that were recorded on November 15. This was under the assumption that the maximum time from one cut to the next flower cut was 8 or 9 weeks.

All data were analyzed by analysis of variance as outlined by Snedecor (5). Analysis of the transformed data was conducted and similar results were obtained.

## Results

*Watering-Mulch Experiment:*—Table I is a summary of bottom break production in each of the various treatments and in the different rows in the benches.

A total of 43 bottom breaks were recorded for the automatic watering-manure mulch treatment. This seems high compared to the total of 30 for the surface watering-manure mulch and constant watering-no mulch treatments, but when the data were analyzed, the differences were found to be insignificant. This would indicate that the various watering treatments and mulches had no effect on the producion of bottom breaks. However, it was shown that there were significant differences between the various rows within the benches and also between the dates of recording the data. This is discussed in more detail in a later paper (1).

## TABLE I—Bottom Break Production in Watering—Mulch Experiment

| Rows | Date of Count | Treatments: Surface Water Manure Mulch | Constant Water No Mulch | Automatic Water Manure Mulch | Constant Water Manure Mulch | Surface Water No Mulch | Total | | Ave/Plot | Ave/Plant |
|---|---|---|---|---|---|---|---|---|---|---|
| I | Nov 15, 1947– | 4 | 6 | 5 | 9 | 10 | 34 | 58 | 5.8 | 0.64 |
| | Jun 12, 1948 | 6 | 6 | 5 | 6 | 1 | 24 | | | |
| II | Nov 15, 1947– | 2 | 2 | 1 | 1 | 3 | 9 | 19 | 1.9 | 0.24 |
| | Jun 12, 1948 | 3 | 1 | 2 | 3 | 1 | 10 | | | |
| III | Nov 15, 1947– | 1 | 3 | 5 | 2 | 2 | 13 | 18 | 1.8 | 0.20 |
| | Jun 12, 1948 | 1 | 0 | 0 | 1 | 3 | 5 | | | |
| IV | Nov 15, 1947– | 2 | 4 | 10 | 6 | 2 | 24 | 40 | 4.0 | 0.44 |
| | Jun 12, 1948 | 1 | 1 | 8 | 1 | 5 | 16 | | | |
| V | Nov 15, 1947– | 2 | 2 | 2 | 1 | 3 | 10 | 19 | 1.9 | 0.24 |
| | Jun 12, 1948 | 0 | 2 | 2 | 3 | 2 | 9 | | | |
| VI | Nov 15, 1947– | 6 | 2 | 2 | 4 | 8 | 22 | 22 | 3.2 | 0.36 |
| | Jun 12, 1948 | 2 | 1 | 1 | 4 | 2 | 10 | | | |
| | Total........ | 30 | 30 | 43 | 41 | 42 | | | | |

*Analysis of Variance*

| Source of Variance | Degrees of Freedom | Mean Square | F |
|---|---|---|---|
| Treatments ....... | 4 | 3.64 | 0.99 |
| Rows.............. | 5 | 25.36 | 6.87** |
| Date of Count .... | 1 | 24.07 | 6.52* |
| Row × Treatments . | 20 | 4.50 | —— |
| Row × Date of Count | 5 | 2.67 | —— |
| Remainder (Error)... | 24 | 3.69 | —— |
| Total........... . | 59 | | |

## TABLE II—Bottom Break Production in Watering—Soil Texture Experiment

| Rows | Date of Count | Treatments: Constant Water Sand | Surface Water Sand | Constant Water Silt | Surface Water Silt | Constant Water Clay | Surface Water Clay | Total | | Ave/Plot | Ave/Plant |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | Nov 15, 1947– | 8 | 11 | 3 | 8 | 4 | 8 | 42 | 51 | 2.1 | 0.70 |
| | Jun 12, 1948 | 4 | 0 | 3 | 0 | 1 | 1 | 9 | | | |
| II | Nov 15, 1947– | 1 | 2 | 3 | 2 | 2 | 1 | 11 | 15 | 0.63 | 0.21 |
| | Jun 12, 1948 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | | | |
| III | Nov 15, 1947– | 0 | 2 | 1 | 4 | 2 | 6 | 15 | 20 | 0.83 | 0.26 |
| | Jun 12, 1948 | 1 | 0 | 1 | 0 | 1 | 2 | 5 | | | |
| IV | Nov 15, 1947– | 0 | 0 | 1 | 1 | 2 | 0 | 4 | 9 | 0.38 | 0.13 |
| | Jun 12, 1948 | 2 | 0 | 0 | 1 | 0 | 1 | 5 | | | |
| V | Nov 15, 1947– | 1 | 1 | 1 | 3 | 2 | 0 | 8 | 9 | 0.38 | 0.13 |
| | Jun 12, 1948 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | | | |
| VI | Nov 15, 1947– | 3 | 5 | 0 | 1 | 1 | 3 | 13 | 16 | 0.67 | 0.23 |
| | Jun 12, 1948 | 0 | 2 | 0 | 0 | 1 | 0 | 3 | | | |
| | Total........ | 20 | 25 | 14 | 21 | 17 | 23 | | 120 | | |

*Analysis of Variance*

| Source of Variance | Degrees of Freedom | Mean Square | F |
|---|---|---|---|
| Treatments............ | 5 | 0.67 | 0.77 |
| Rows.................. | 5 | 10.37 | 11.92** |
| Date of Count......... | 1 | 30.25 | 34.77** |
| Replications.......... | 1 | 0.69 | —— |
| Rows × Treatments..... | 25 | 0.97 | —— |
| Rows × Date of Count... | 5 | 5.52 | —— |
| Remainder (Error)...... | 101 | 0.87 | —— |
| Total................ | 143 | | |

*Watering-Soil Texture Experiment:*—Table II is a summary of bottom break production from the two replications of treatments on one bench. (Each figure in the table represents the sum of two of the replications). The analysis was computed on a per replicate basis.

The highest and lowest production of bottom breaks per plot for all rows was surface watering-sandy loam and constant watering-silt loam respectively. These figures when analyzed were not significantly different, possibly showing that none of the treatments in the experiment influenced the production of bottom breaks appreciably. On the other hand, as shown in the previous experiment, the location of the row in the bench makes a difference in the occurrence of basal breaks. This also will be discussed in a later paper (1).

## Summary

Counts were made of bottom break producion of rose plants growing under different methods of watering and in different soil textures. Analysis of the data revealed no significant differences in bottom break production as a result of the various treatments.

### Literature Cited

1. Fischer, Charles, W. Jr., and Kofranek, Anton M. Bottom break production of rose plants as influenced by plot location in the greenhouse. *Proc. Amer. Soc. Hort. Sci.* (In Press).
2. Post, Kenneth, and Seeley, John G. Automatic watering of greenhouse crops. *Cornell Univ. Agr. Exp. Sta. Bul.* 793: 1–26. 1943.
3. ———— Automatic watering of roses 1943–1946. *Proc. Amer. Soc. Hort. Sci.* 49: 433–436. 1947.
4. ———— The constant water level method of watering roses. *Proc. Amer. Soc. Hort. Sci.* 49: 441–443. 1947.
5. Snedecor, George W. Statistical Methods. Iowa State College Press, Ames, Iowa. 4th Edition, 1946.
6. Spurway, D. H. Soil testing. *Mich. Tech. Bul.* 132. 1935.

# Some Effects of Sodium Selenate on Greenhouse Carnations Grown in Gravel[1]

By GEORGE BEACH, *Colorado A. & M. College, Fort Collins, Colo.*

GOOD control of red spider mite (*Tetranychus telarius*) is obtained at the Colorado Experiment Station by fumigation with Azofume at the first sign of spider after benching the plants and then preventing later infestation by using sodium selenate ($Na_2SeO_4$) in the nutrient solution.

It was noted, however (1) that when 10 ppm of sodium selenate was added to the nutrient solution each week for several weeks, there was a marked check in growth of carnation plants in gravel. Kiplinger (4) stated that 10 ppm per week of $Na_2SeO_4$ appeared to be the most satisfactory method of controlling red spider and aphids on carnations in gravel.

To find how little Se could be used in nutrient solution to give effective red spider control without stunting the plant growth, a series of gravel culture plots was set up in which the nutrient solution was identical on all plots with the exception of Se content. Five different levels of Se and an untreated check plot were compared. The variety Red Spectrum Supreme was used in this test.

## MATERIALS AND METHODS

The nutrient solution was a Colorado modification of the Ohio WP solution containing:

| | | | | |
|---|---|---|---|---|
| 500 | ppm | $NO_3$ | from | $NaNO_3$ |
| 100 | ppm | $PO_4$ | from | $Ca(H_2PO_4)_2$ |
| 250 | ppm | K | from | KCl |
| 300 | ppm | Ca | from | $CaSO_4$ and $Ca(H_2PO_4)_2$ |
| 50 | ppm | Mg | from | $MgSO_4$ |
| 25 | ppm | $NH_4$ | from | $(NH_4)_2SO_4$ |
| 2 | ppm | Fe | from | $FeSO_4$ |
| 2 | ppm | Mn | from | $MnSO_4$ |
| ½ | ppm | B | from | $H_3BO_3$ |

The solution above at half strength was used for the first 10 days. Thereafter it was full strength. This solution was used for 8 weeks, during which time it was tested every 2 weeks for N, P, and K (Spurway method). Salts were added as these tests indicated a need. The old solution was discarded at the end of 8 weeks and replaced by a fresh one.

Since 10 ppm sodium selenate per week added to a nutrient solution (1) had proven to be too much, the maximum used in this test was 8 ppm. The other treatments were 7 ppm, 6 ppm, 4 ppm, added per week, 8 ppm every 2 weeks for 8 weeks and an untreated check plot.

Fig. 1 shows how these applications compare with the amount recommended on the sodium selenate package for treatment of soil.

[1]Scientific Series paper No. 285, Colorado Agricultural Experiment Station.

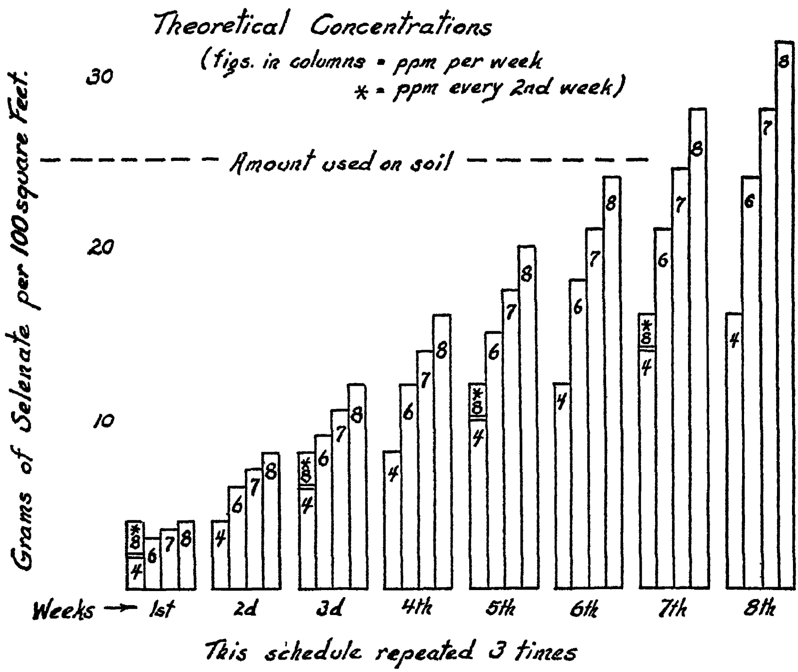


FIG. 1

Se treatments were started June 22, 6 weeks after benching the plants, which were rooted cuttings direct from the propagating bench.

Fig. 2 shows the type of plots and arrangement of plants. There were 16 plants per plot in four rows of four plants. Eighteen such plots provided three blocks of six plots each. The five different Se levels and untreated check plot were located at random in each of these three blocks.

Se treatment was continued for 24 weeks, by repeating the original 8-week treatment three times.

Per 100 square feet of bench surface, (Fig 1) the minimum treatment required 2 grams of selenate per week or 16 grams for 8 weeks. Repeating this schedule three times required 48 grams per 100 square feet for the 24 weeks during which Se was used. On the maximum treatment, double these amounts was used. Other treatments were intermediate amounts.

## RESULTS

Differences between treatments became apparent gradually a few weeks after the Se treatments were started. These differences became more apparent with time and were most striking at the end of the Se treatment in December. Before flowers were produced, Se injury was apparent in two ways: plants were shorter and they made more

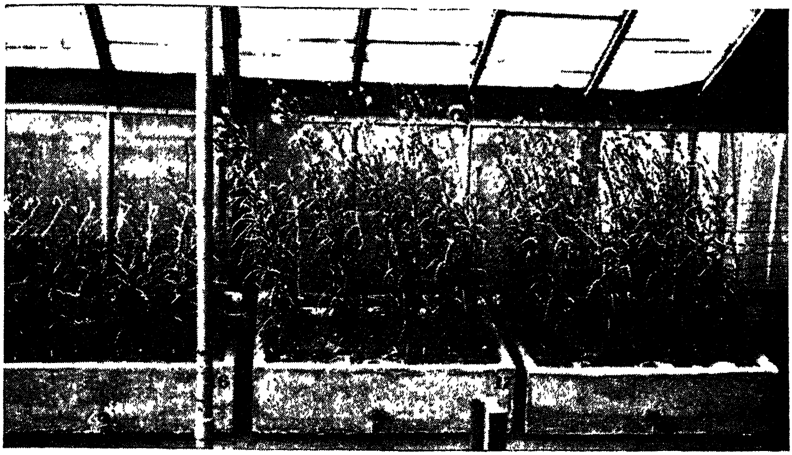

FIG. 2. Appearance of plants at the end of Se treatment in December. Plot 16 (left) – maximum treatment; 8 ppm $Na_2SeO_4$ added each week for 8 weeks and repeat with fresh solution. Treatment continued 24 weeks. Plot 17 (center) – check plot; no selenium. Plot 18 (right) – minimum treatment; same as Plot 16 except that 4 ppm $Na_2SeO_4$ used.

sideshoots. Such symptoms were noticeable but least apparent on the minimum treatment, and were progressively more pronounced up to the maximum Se treatment.

In December, when the Se treatment was discontinued (see Fig. 2), plants on the maximum Se treatment were only half as tall as the untreated check and were profusely branched and densely crowded with small, weak shoots.

Flowers had been cut 10 times on the check plots and production was near two flowers per plant, before any flowers were cut on the maximum Se treatment. The symptoms on the other treatments at this time were similar but progressively less pronounced, down to the minimum treatment. Even on the minimum treatment plants had definitely been injured, as shown by an average 3 to 4 inches less height, weaker stems and more branching of plants.

Azofume fumigation was given late in June and was not required again on these plots. The untreated check plots, however, became reinfested with spider in fall and in spring.

## Nutrient Solutions

It might be suspected that different demands upon the nutrient solution would be made by the considerable differences in plant growth on the various Se treatments. Tests for N, P, K, and pH were made every 2 weeks and salts were added as needed to bring the solution up to full strength. There is no appreciable difference in these averages, regardless of the treatment or the position of the plot on the bench.

The average tests for the year do not tell the whole story, however. Additions of nitrate were necessary eight times starting in October while phosphate was added 18 times starting in June and potash was added only six times starting in October. But this holds for all Se treatments as well as the untreated check plots.

The average pH of all plots throughout the season was 6.85 with little variability between plots. For the check plots it was 6.87 and ranged from 6.76 to 6.92 for the five Se treatments. From June to November, pH rose gradually from 6.6 to 7.3, the highest for the year. The lowest pH was 6.2 at the end of January. Variation in pH of the check plots throughout the year was practically identical to that in the Se treatments.

## Discussion

*Se Injury:*—Beath and Eppson (2) state: "it is not uncommon for a dependable Se-absorbing plant to accumulate 1000 to 2000 ppm of Se when rooted in a soil carrying 2 to 5 ppm Se". While it is not known whether or not the carnation is a "dependable" absorber, it is known to absorb enough Se to keep the plant free from red spider (4, 5). These workers stated that with carnations 45 to 100 ppm of selenium in the foliage was effective in the control of red spider.

Hurd-Karrer (3) has found no plant that fails to take up appreciable quantities of selenate Se, although she does not specifically mention carnation. She found that Se produced chlorosis and severe stunting of wheat plants when the selenium to sulphur ratio in either nutrient solution or soil was 1:4. Plant analysis showed that 1300 ppm Se had been concentrated in the plant tissue when they were grown in nutrient solution containing from 4 to 24 ppm Se. A Se/S ratio of 1:8 produced slight chlorosis and 500 ppm Se in the plant, while a ratio of 1:16 produced normal plants with 180 ppm Se in the plant tissue.

The minimum treatment in this experiment had a Se/S ratio of 1:188 when Se was first added (see Table I). The ratio for the maximum treatment during the first week was 1:94. No sulfur was added during the 8-week life of the nutrient solutions so that theoretically these ratios were narrowed by the weekly additions of selenate, until the eighth week when they were 1:23 to 1:12 respectively, for maximum and minimum treatments.

It was thought that these small weekly additions of Se would be

TABLE I—Se/S Ratio†

| Treatment (Ppm) | Weeks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th |
| 4 | 1:188 | 1:94 | 1:63 | 1:47 | 1:38 | 1:31 | 1:27 | 1:23 |
| 8* | 1:94 | 1:94 | 1:47 | 1:47 | 1:31 | 1:31 | 1:23 | 1:23 |
| 6 | 1:125 | 1:52 | 1:42 | 1:31 | 1:25 | 1:21 | 1:18 | 1:16 |
| 7 | 1:108 | 1:54 | 1:36 | 1:27 | 1:22 | 1:18 | 1:15 | 1:13 |
| 8 | 1:94 | 1:47 | 1:31 | 1:23 | 1:19 | 1:16 | 1:13 | 1:12 |

*Ppm every 2 weeks.

†First week, are actual ratios at the beginning of treatment, thereafter ratios are theoretical on the basis of amounts of Se added.

less harmful than a single, larger application. Apparently, however, carnation responds to Se much as does wheat (3) since some injury was noted on the minimum treatment where the theoretical Se/S ratio reached 1:23 in the eighth week. During the entire 24 weeks of Se treatment this ratio prevailed for 3 weeks.

When sodium selenate is used on soil 25 grams per 100 square feet of bench surface is usually not harmful. Twice this amount has been used (4, 5) with little or no injury to carnations. Twenty-five grams is the rate recommended on the package. This is approximately 6 ppm actual Se. To have a Se/S ratio of 1:16 would require 300 ppm $SO_4$ in the soil. It is possible that the use of Se on soil even at the recommended rate may stunt growth if the $SO_4$ test is lower than 300 ppm. The inhibition of selenium toxicity by gypsum has been noted (4) but this work makes no mention of the specific ratio of Se to S when the total soil sulfate is considered.

Some recovery from Se injury was noted each time the 8-week-old nutrient solution was discarded and replaced by new solution with the wide Se/S ratio (Table I).

One other abnormality occurred on the Se treatments that was not present on the untreated checks. Some of the cut flowers developed a constriction on the second to fourth internode below the flower. This constriction was a wilted section of the stem 5 to 10 mm in length. This damage occurred the first to the fourth day after cutting the flower and while all the stem except this localized small section remained normally fresh. The stem, so weakened, could no longer support the weight of the flower, which hung inverted, with a sharp bend in the stem at the constriction. Sometimes the flower remained fresh a day or so longer; but usually withered quickly after falling over. This injury occurred only during February, 2 months after the Se treatment had been discontinued. One-half of the flowers on the maximum treatment and one-fourth of those on the 6 ppm and 7 ppm treatments were so affected. This abnormality was not shown by the minimum treatment or the check plots.

## Yield of Cut Flowers

A complex variance analysis[2] of the yield data shows that the variability *between grades within treatments* is very highly significant.

Considering the total yields of all grades of flowers there is no significant difference between treatments although there is a gradual increase in yield with increase in amount of selenium used.

Table II show that there were significantly more first grade flowers on the check than on any other treatment. And there were less "shorts" and thirds on the check than on other treatments. The only grade where significant differences were not shown is in the "splits".

[2]Calculation by Nellie Lanblom, Colorado A. & M. statistitian.

TABLE II—YIELD OF CUT FLOWERS

| Treatment | Number of Flowers | | | | |
|---|---|---|---|---|---|
| | 1st | Short | 3rd | Split | Total |
| Check | 237 | 20 | 43 | 42 | 342 |
| 8 x | 154** | 99** | 64 | 24 | 341 |
| 4 | 165* | 112** | 44 | 33 | 354 |
| 6 | 71** | 139** | 95 | 82 | 387 |
| 7 | 71** | 89* | 150** | 92 | 402 |
| 8 | 54** | 74 | 217** | 54 | 399 |
| Total | 752 | 533 | 613 | 327 | 2,225 |

Un-graded cut
6/1 154

X = ppm every 2 weeks 2379 (8.3 flowers per plant)
Minimum difference between treatments within grades required for significance: *.05 — 18.708
**.01 = 24.951

## SUMMARY

Applications of sodium selenate to nutrient solution at different times and in varying amounts on gravel-grown carnations gave good protection from red spider mite. Plant growth was progressively more stunted as the ratio of selenium to sulfur was narrowed in the nutrient solution. The smallest application proved to be too much as far as maintenance of quality in cut flowers is concerned. The work is being continued using smaller applications of selenium.

### LITERATURE CITED

1. MUSSENBROCK, A., and BEACH, G. A. Cost comparisons—Gravel-grown carnations. *Proc. Amer. Soc. Hort. Sci.* 51: 623–626. 1948.
2. BEATH, A. O., and EPPSON, H. F. The form of selenium in some vegetation. *Wyo. Sta. Bul.* 278. 1947.
3. HURD-KARRER, ANNIE M. Relation of sulfate to selenium absorption by plant. *Amer. Jour. Bot.* 25: 666–675. 1938.
4. KIPLINGER, D. C., and FULLER, GLEN. Selenium studies with some flowering greenhouse plants. *Proc. Amer. Soc. Hort. Sci.* 47: 451. 1946.
5. WHITE, HAROLD E., and WHITCOMB, WARREN. Sodium selenate for red spider control in Massachusetts. *Proc. Amer. Soc. Hort. Sci.* 47: 503. 1946.

# The Use of 2,4–D as a Pre-Emergence Spray for the Control of Weeds in Gladioli, Daffodils, and Dutch Iris[1]

By J. Mitchell Jenkins, Jr., *Vegetable Research Laboratory, Wilmington, N. C.*

Flower growers in North Carolina are often confronted with the problem of weed control in the production of gladioli, Dutch iris, and daffodils for the wholesale flower market. The weed problem is usually not serious in the case of daffodils because they grow during cold weather when weed growth is slow, but sometimes chickweed, henbit, and certain other cold weather species must be controlled. Chickweed also makes a vigorous growth in the protected beds in which Dutch iris are forced, making it necessary to hoe and weed them by hand which is another costly operation in the production of the flowers.

The control of weeds in gladioli is probably one of the worst problems as far as the average flower grower is concerned. Not only do weeds make rank growths in the blooming sizes of gladioli late in the season but they also grow up among the small cormels that are grown each year for planting stock. Hoeing and weeding by hand is slow and expensive but it has been the only practical method of getting rid of the weeds. However, Krone and Hamner (1) reported in 1947 that 2,4–D could be used on certain types of soil to control weeds in gladioli.

When the Vegetable Research Laboratory began operations 2 years ago one of the first projects was a study of the effectiveness of different herbicides in the control of weeds in flower plantings. In preliminary studies it was found that a water soluble ammonium salt of dinitro-o-sec-butylphenol, sold as Dow Selective Weed Killer, could usually be used on Dutch iris at any time up to bud formation without injury to the plants provided that it was applied in dilutions of 1 or 2 parts of the herbicide (depending upon the air temperature) to 800 parts of water. It could not be used safely on daffodils or on gladioli in concentrations strong enough to give good control of weeds.

In 1947 a number of tests of 2,4–D were made in which the herbicide was used both as a post-emergence and as a pre-emergence spray.[2] It was found that it caused injury to daffodils if applied after the plants had emerged from the ground. Gladioli could be sprayed at the rate of 1 pound of 2,4–D per acre without apparent injury provided the plants were not more than 4 or 5 inches tall. Larger plants were injured to some extent, but the injury was minimized by adjusting spray nozzles so that the spray was directed toward the bases of the plants and not on top of them. Weed control, however, was not as good as was desired.

Where 2,4–D was used as a pre-emergence spray with fall-grown gladioli the results were entirely satisfactory (2). Figs. 1 and 2 show

[1]Approved by the Director of the North Carolina Agricultural Experiment Station as Paper No. 305 of the Journal Series.

[2]The amine form of 2,4–D was used in these tests.

FIG. 1. Growth of weeds in experimental planting of Picardy gladioli (check plot).

the effects of using 8 pounds per acre on gladioli as a pre-emergence treatment as compared to no treatment and no cultivation. The material was sprayed on the soil surface 2 days after the gladioli had been planted. It was followed in 7 hours by a half inch of rain. Thereafter it did not rain again until the plants began to bloom. This treatment gave no better weed control than another treatment in which 4 pounds of 2,4–D per acre was sprayed on the soil as a pre-emergence treatment. It gave much better weed control than 1 pound per acre used as a post-emergence spray when the plants were 3 inches tall.

The application of 8 pounds per acre of 2,4–D on a soil that was classified as Onslow loamy fine sand caused no observable injury to gladioli, and it gave almost complete control of weeds from August 5 until the plants had stopped blooming in early November. The weeds that were killed included crab grass *(Digitaria sanguinalis)*, goose grass *(Eleusine indica)*, Richard's weed *(Richardia scabra)*, *Crotolaria striata*, and others that were not identified. The application of 8 pounds per acre is more than would be required in commercial practice, but this amount was used in order to determine whether or not there would be injury to the gladioli. Since no injury was observed, it it believed that amounts up to 8 pounds per acre can be used safely as a pre-emergence treatment. In most cases it would be safer and more economical to apply 2,4–D at the rate of 4 pounds per acre. After the herbicide has been applied the planting should not be cultivated until the plants reach a height of 12 inches or more and even then cultivation is not necessary unless more soil is needed around the bases of the plants to support them.

FIG. 2. Weeds controlled in this plot of Picardy gladioli by use of a pre-emergence spray of 8 pounds of 2,4-D per acre (Wilmington, N. C., 1948).

Where gladioli were planted in the late winter or early spring the application of 2,4–D was delayed until small weeds began to appear or until a few days before the plants began to emerge. The material was not very effective when applied before the weed seeds began to sprout or while they were still in a dormant condition.

In tests of 2,4–D on Dutch iris and daffodils satisfactory control of weeds, without injury to the plants, was obtained from the use of 3 pounds per acre applied as a spray from 2 to 5 days after the bulbs were planted. If the soil was very dry the beds were watered 2 or 3 days before the treatment was applied to cause weed seed to soften and sprout.

In these tests it was found that 2,4–D used as a pre-emergence spray sometimes *did not* give satisfactory control of weeds under the following conditions:

1. If the soil was so dry that the weed seeds did not sprout before the herbicide was applied.

2. When 2,4–D was applied during cold weather, followed several weeks later by warm weather as often occurs with early spring plantings of gladioli. Under these conditions warm season weeds often emerged. The dormant seeds had apparently not been affected by the herbicide.

3. When frequent rains followed the application of 2,4–D. Besides dilution and leaching of the material under these conditions, many weed seed were floated to the surface of the soil from below the effective penetrating depth of the 2,4–D.

## Summary

Several tests of 2,4–D on gladioli, Dutch iris, and daffodils indicate that satisfactory control of weeds in plantings of these flower crops may often be obtained by the use of from 2 to 4 pounds per acre applied as a pre-emergence spray.

## Literature Cited

1. Krone, Paul R., and Hamner, Charles L. 2,4–D treatment for the control of weeds in plantings of gladioli. *Proc. Amer. Soc. Hort. Sci.* 49 : 370–378. 1947.
2. Jenkins, J. Mitchell, Jr. Pre-emergence spray is bulb boon. *Southern Seedsman* 12: 30 and 43. February, 1949.

# Effect of Fertilizer Treatments on Yield of Bay Leaves, Oil, and Phenol

By A. J. LOUSTALOT, *Federal Experiment Station, Mayaguez, Puerto Rico*

THERE is considerable acreage of steep and rolling land in Puerto Rico that is for the most part either lying idle or yielding little or no profit. The bay rum tree, *Pimenta racemosa* (Mill.) Moore, is a crop which can be grown successfully on much of this type of land (1). Several groves and scattered clumps of bay rum trees are already well established in Puerto Rico with a total area approaching 1000 acres. These groves are located in the central and southern portions oi the island, mainly in the southeast section near Guayama.

Although the tropical upland soils on which bay rum trees are grown in Puerto Rico are likely to be deficient in nitrogen and other mineral nutrients, fertilization is not generally practiced. There are no experimental data available as to the effect of fertilizer application on the vegetative growth, oil content of the leaves or on the frequency of harvests. One grower has stated that he applied ¾ pound per tree of a 10–6–16 fertilizer in April and the following year obtained double the total leaf production that he obtained the previous year. There was no noticeable effect of the fertilizer on the percentage of oil in the leaves. However, there was no check plot to prove that the increased leaf production was due entirely to the fertilizer and not in part to weather conditions or other factors.

In order to obtain some information as to the influence of commercial fertilizers on the vegetative growth and percentage oil and phenol in the leaves, the following experiment was carried out in cooperation with Mr. Arturo Figaredo, a bay grower and distiller near Guayama, Puerto Rico.

## MATERIALS AND METHOD

The site selected for the experiment was more or less typical of the bay producing areas of the island. The soil type was Descalabrado silty clay located on a hillside with a 55 per cent slope. Several hundred bay rum trees, 6 or 7 years old, spaced 5 to 6 feet apart in uneven rows were growing on the hillside.

Five fertilizer treatments were applied to five replications arranged in Latin square design. Each replication consisted of 15 trees selected for uniformity. The trees were about 6 inches in diameter and about 15 feet high. The fertilizer treatments were as follows: (a) Ammonium sulfate at 3 pounds per tree, (b) superphosphate (40 per cent) at 1½ pounds per tree, (c) muriate of potash (60 per cent) at 2 pounds per tree, (d) complete fertilizer (the same kind and rates as in treatments a, b, and c), and (e) check. Because of the steep slope the fertilizer was applied in a shallow semi-circular trench on the upper side of the tree about 3 feet from the trunk. The fertilizer was covered with soil to minimize the loss from washing from frequent heavy rainfalls. The fertilizer was applied in May 1947 about 2 weeks after the trees had been stripped of their leaves for the current harvest. The experi-

mental trees were again harvested in September 1948, about 16 months after the fertilizers were applied. In normal times, 14 to 18 months is considered an average interval between harvests in Puerto Rico. All the leaves and new shoots from the 15 trees in each plot were harvested and weighed before being distilled and the average yield of fresh vegetative growth per tree in each replication determined. A composite sample of about 250 to 300 pounds of fresh material from each plot was steam-distilled under commercial conditions and the percentage oil determined. The percentage phenol in the oil from each distillation was also determined.

## Results

The effect of fertilizer treatments on the yield of fresh vegetative growth, average oil and phenol content are presented in Table I. It is evident from these data that nitrogen applied in the form of ammonium sulfate at the rate of 3 pounds per tree alone or in combination with potassium or phosphorus significantly increased the yield of fresh vegetative growth. Muriate of potash or superphosphate alone or combined did not increase the yields significantly nor did potassium and phosphorus when applied with ammonium sulfate affect the yields significantly. There was no statistically significant difference in the percentage of oil or phenol among any of the treatments.

The cost of ammonium sulfate at present in Puerto Rico is $90 a ton or 4.5 cents per pound. The cost of applying ammonium sulfate in this experiment would amount to 13.5 cents per tree plus labor. Assuming an average yield of 0.1 per cent oil for both treated and check trees, the treated trees yielded an average of .076 pound of oil more per tree than untreated trees. With bay oil selling at $1.00 or less a pound on the present market the value of the additional oil from treated trees would amount to 7.6 cents per tree, about half the cost of the fertilizer. Unless the price of bay oil increases appreciably, it is obviously uneconomical to apply ammonium sulfate to bay trees at the rates tested. Since the trees responded only to nitrogen this element may be supplied more economically by growing a leguminous cover crop.

TABLE I—Effect of Fertilizer Treatments on Yield of Bay Leaves, Percentage of Oil and Phenol

| Fertilizer Treatment | Rate Per Tree (Lb) | Average Yield of Fresh Vegetative Growth Per Tree* (Lb) | Average Oil in Fresh Material† (Per Cent) | Average Phenol in Oil‡ (Per Cent) |
|---|---|---|---|---|
| Ammonium sulfate | 3 | 30.8 | 0.98 | 58.6 |
| Ammonium sulfate<br>Muriate of potash (60 per cent)<br>Superphosphate (40 per cent) | 3<br>1½<br>2 | 28.0 | 1.04 | 58.0 |
| Superphosphate (40 per cent) | 2 | 26.0 | 1.00 | 59.0 |
| Muriate of potash (60 per cent) | 1½ | 24.4 | 0.97 | 58.0 |
| Check | — | 23.2 | 0.93 | 58.8 |

*Average of 75 trees.
Least significant difference at 5 per cent level = 4.0 pounds.
†Least significant difference at 5 per cent level = 0.15 per cent.
‡Least significant difference at 5 per cent level = 2.0 per cent.

## Summary

The following fertilizer treatments were applied to bay trees: (a) ammonium sulfate at 3 pounds per tree, (b) muriate of potash (60 per cent) at 1½ pounds per tree, (c) superphosphate (40 per cent) at 2 pounds per tree, (d) complete fertilizer (the same kind and rates as in treatments a, b, and c), and (e) check.

1. Ammonium sulfate alone or in combination with potassium or phosphorus significantly increased the yield of fresh vegetative growth.

2. Muriate of potash or superphosphate alone or combined did not increase the yields of vegetative material significantly nor did potassium and phosphorus when applied with ammonium sulfate affect the yields significantly.

3. There was no statistically significant difference in the percentages of oil or phenol among any of the treatments.

4. Fertilizing bay trees with ammonium sulfate as in this experiment was uneconomical at present prices. The value of the additional oil obtained from trees treated with ammonium sulfate amounted to about half the cost of the fertilizer.

## Literature Cited

1. Childers, N. F., Seguinot Robles, P., and Loustalot, A. J. Bay oil production in Puerto Rico. *Puerto Rico (Mayaguez) Fed. Exp. Sta. Cir.* 30. 1948.

# The Use of Sodium Selenate as a Control for Cyclamen Mite, Tarsonemus Pallidus Banks[1]

By George S. Haight, *Iowa State College, Ames, Iowa*

The use of sodium selenate as a control for cyclamen mite, *Tarsonemus pallidus* Banks, on cyclamen has met with varying degrees of success by investigators and commercial growers. Kiplinger and Fuller (1) in some preliminary investigations found it to be of questionable value on a group of cyclamen, as it stunted the plants severely although it apparently controlled the mite. The following investigation was undertaken to determine the effectiveness of sodium selenate as a control for cyclamen mite, and also to determine the effect of the selenate on the vigor of the plant, the number of blossoms produced, the plant's commercial value, and whether or not blooming was delayed or hastened.

Sodium selenate was applied to the soil by two methods, namely: The water soluble $Na_2SeO_4$, which was watered on the soil; and P–40, a proprietory material containing 2 per cent by weight of sodium selenate impregnated on superphosphate, which was broadcast on the surface of the soil. P–40 was applied at rates to give equivalent amounts of sodium selenate per pot. As it was also desired to observe the effect of sulfur, the treatments were repeated with the addition of sulfur in the form of dusting sulfur at approximately 9 to 12 times the weight of the $Na_2SeO_4$. Another factor which was tested was that of the time interval between applications. To test this, the same total amount of selenate was applied to the plants in four applications instead of two. For this purpose the time interval was 11 weeks between applications for plants receiving two treatments, and 5½ weeks for plants receiving four applications. Four rates of application were used. A complete list of treatments and checks is shown in Table I.

TABLE I—Table of Treatments

| No. of Treatment | Kind of Treatment |
|---|---|
| 1 | 1.25 mg/gal $Na_2SeO_4$ |
| 2 | 1.00 mg/gal $Na_2SeO_4$ |
| 3 | 0.75 gm/gal $Na_2SeO_4$ |
| 4 | 0.50 gm/gal $Na_2SeO_4$ |
| 5–8 | Same amounts as above, plus sulfur |
| 9–16 | Same as 1–8, but applied in four applications instead of two |
| 17–32 | Same as 1–16, with P-40 used at equivalent rates |
| 33–36 | Sulfur added to soil; treated as checks |
| 37–40 | Checks |

## Method and Procedure

Four hundred plants of a dark salmon variety were secured from a commercial grower and potted in 2½-inch pots on February 27, 1947. A soil mixture composed of equal parts of Webster loam, sand and leaf mold was used as the potting media. The plants were grown on until May 14, when 320 of the most uniform were selected for the experiment and arranged in eight randomized blocks of 40 plants per

[1]Journal Paper No. J–1573 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 926.

block. It was thought that the plants were sufficiently well established at this time to prevent any toxicity manifesting itself in the form of stunting. A small group of plants which had been treated early in April were markedly stunted during the entire growing period. At the time of the first application of selenate, the plants were free of pests.

The original and subsequent treatment dates were: May 14, all plants; June 22, only plants receiving four applications; July 27, all plants; August 30, only plants receiving four applications.

On May 24 the plants were shifted to 4-inch pots, for which the following soil mixture was used: Three parts Webster loam, two parts leaf mold, two parts rotted cow manure, and one 4-inch pot of 4–12–4 fertilizer to each 2 bushels of soil mixture. The soil around the top of the hypocotyl, which is normally rubbed off at the time of shifting in order to elevate the hypocotyl, was mixed with the soil for each pot to retain all of the selenate, since the plants had been treated only a short time before.

The plants were given the normal commercial treatments for shading, watering, ventilation, staging, and fertilization. All soils and pots were sterilized as a precaution against nematode. A nicotine sulfate spray was applied once, before the plants were treated with selenate, to control a minor infestation of aphids on some of the plants. No other attempts were made at insect control during the entire experiment, although thrips and aphids were present. Casual observation seemed to indicate that the check plants were more heavily infested than the treated plants.

Each plant was artificially infested with mite three times during the growing season. The most effective method of transfer was to section pieces of leaf or flower which contained the desired number of mite. This was done with the use of a binocular microscope. The leaf or flower section was then placed in the crown of the plant. The author was limited by an inadequate supply of mite for the first infestation, and hence a minimum of two mites was placed on each plant on June 1. It was thought that the plants would have absorbed sufficient selenium by this time to be toxic to the mites. Subsequent infestations of 8 and 20 mites per plant were made on October 14 and November 7, respectively.

## Scoring

An individual plant record was kept of the blooming date and degree of injury, if any, on each flower. Each plant was scored on the basis of injury, if any, on each flower. Each flower was scored on the basis of the severity of mite injury on a scale of 0 to 4, the latter being the most severe type of injury in which the blossoms failed to open. A zero reading indicated no mite injury whatsoever. Readings were taken on a weekly basis from January 14 to February 11. On February 14 the plants were judged on their commercial value by a committee of three judges.

## Results

Since there were a large number of zero readings recorded in the data (of the 256 treated plants, 122 showed no mite injury), the assumptions which are normally made under the analysis of variance were no longer valid. In order to secure a measure of reliability, a new

non-parametric test was applied. Inherent in this test which has only recently been devised by Drs. Mood and Brown of the Statistical Laboratory at Iowa State College and has not as yet been published, is the fact that the median is the best estimate of the treatment effect. This accounts for the zero values for the last three rates.

From the results of this analysis we may assume that both $Na_2SeO_4$ and P-40 gave equally good control at the three higher rates of application, but that the lowest rate of application of 0.50 gm/gal did not give as complete a control (Table II).

TABLE II—Effect of Mite Injury on Flowers

| Rate of Application (Gm/Gal) | Median Value |
|---|---|
| 0.50 | 0.25 |
| 0.75 | 0.00 |
| 1.00 | 0.00 |
| 1.25 | 0.00 |

$X^2$ = 23.798 for three degrees of freedom highly significant at 1 per cent level.

An analysis of variance of the number of blossoms, the number of blossoms and buds, and the commercial value of the plants showed no significant differences between the treated and the check plants in the number of blossoms and the number of blossoms and buds. There was a highly significant difference at the 1 per cent level for the commercial value. The untreated plants were so much inferior to the treated plants because of the severe mite injury that they were unsuitable for commercial purposes (Fig. 1).

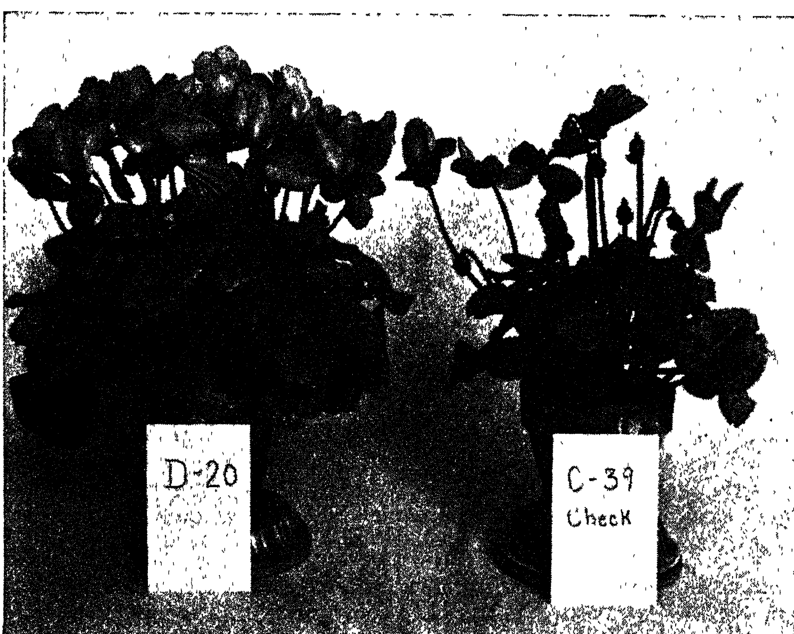


Fig. 1. Difference in mite injury between treated and untreated plants.

Highly significant differences existed among the treatments only for the form of selenate and the rate of application. The addition of sulfur and the two time intervals showed no significant differences. There was no interaction between any of the four factors except with P–40 at the 0.75 gm/gal rate. The author has no explanation for this deviation.

The highly significant differences between methods showed that P–40 reduced the number of flowers (Table III), flowers and buds

TABLE III—MEAN NUMBER OF FLOWERS BY METHODS AND RATE OF APPLICATION

| Method | Rate of Application (Gms/Gal) | | | | Mean |
|---|---|---|---|---|---|
| | 0.50 | 0.75 | 1.00 | 1.25 | |
| $Na_2SeO_4$ | 12.72 | 11.53 | 9.59 | 7.91 | 10.44 |
| P-40 | 10.81 | 5.28 | 7.44 | 4.53 | 7.02 |
| Mean | 11.77 | 8.41 | 8.52 | 6.22 | |

Standard error between methods ... ±0.50
Standard error between rates ... ±0.70
Standard error of rate within methods ... ±0.99

(Table IV), and the commercial value (Table V) more than the water soluble $Na_2SeO_4$. The differences between rates of application showed that, for each of the above characteristics, there was a decrease in the score with an increase in the rate of application of either form of selenate.

TABLE IV—MEAN NUMBER OF FLOWERS AND BUDS BY METHODS AND RATE OF APPLICATION

| Method | Rate of Application (Gms/Gal) | | | | Mean |
|---|---|---|---|---|---|
| | 0.50 | 0.75 | 1.00 | 1.25 | |
| $Na_2SeO_4$ | 21.59 | 20.34 | 18.34 | 16.25 | 19.13 |
| P-40 | 21.22 | 11.84 | 16.66 | 12.50 | 16.24 |
| Mean | 21.41 | 16.09 | 17.50 | 14.38 | |

Standard error between methods ... ±0.72
Standard error between rates ... ±1.01
Standard error of rate within methods ... ±1.43

TABLE V—MEAN OF JUDGES' SCORES WITH RELATION TO METHODS AND RATE OF APPLICATION

| Method | Rate of Application (Gms/Gal) | | | | Mean |
|---|---|---|---|---|---|
| | 0.50 | 0.75 | 1.00 | 1.25 | |
| $Na_2SeO_4$ | 3.54 | 3.52 | 3.13 | 2.93 | 3.28 |
| P-40 | 3.08 | 2.17 | 2.76 | 2.08 | 2.52 |
| Mean | 3.31 | 2.85 | 2.95 | 2.51 | |

Standard error between methods ... ±0.10
Standard error between rates ... ±0.14
Standard error of rate within methods ... ±0.19

## SUMMARY

1. Cyclamen plants treated with $Na_2SeO_4$ produced more flowers and buds and had greater commercial value than plants treated with P–40.

2. There was no difference in the effectiveness of control of cyclamen mite between $Na_2SeO_4$ and P–40. However, P–40 would not be a practical control for commercial growers to use, because of the effect it had on the plants and the difficulty of applying it in accurate amounts in commercial pot culture.

3. The addition of sulfur in the form of dusting sulfur was of no value to plants treated with sodium selenate.

4. Two applications of $Na_2SeO_4$ or P–40 spread over a given interval of time were better than the same amount of selenate applied in four applications over the same time interval, because of the equal efficiency and less work involved.

5. Treatment of cyclamen at the rate of 0.75 gm/gal was a good but not 100 per cent control of cyclamen mite. Lower applications do not give sufficient control, while larger applications reduce the number of flowers and the plant's commercial value.

## Literature Cited

1. Kiplinger, D. C., and Fuller, Glen. Selenium studies with some flowering greenhouse plants. *Proc. Amer. Soc. Hort. Sci.* 47: 451–462. 1946.

# Marketing of Prepackaged Flowers

By JOHN L. SWINGEN, WILLARD G. BRYANT, and ALEX LAURIE,
*Ohio Agricultural Experiment Station, Wooster, Ohio*

To investigate the marketing phase of the prepackaging method of handling cut flowers described by Hauge, Bryant, and Laurie (1), a packaging operation was set up at Ohio State University to learn of the possibilities and practical values of prepackaging flowers. To accomplish this research, a selling corporation was organized under the name of Flora Pak Research Corporation to obtain information on the distribution, sale, and public acceptance of packaged flowers. The flowers were offered for sale through the normal channels of flower distribution, the retail flower shops, and also through the chain-store supermarkets.

The procedure for packaging closely followed the recommendations set forth in the research data earlier reported (1) namely: (a) the use of a waterproofed tray to protect the flowers from handling bruises, and to prevent loss of the added moisture; (b) the use of a transparent, moisture and gas proof film that prohibits the exchange of gasses or loss of moisture from the package, and which presents an attractive medium to display the contents of the package for public appeal; (c) the careful selection of freshly cut, properly handled stock; and (d) the required refrigeration and recommended storage limitations to insure excellent quality to the consumer. The flowers for processing were purchased on the open market until such time as the volume warranted interest on the part of growers who felt they would like to determine the effect of contract pricing.

Following the advent of this period, a more stable market price could be maintained and sales more closely anticipated. The flowers were processed manually for distribution and sale, hand sealing the pre-cut cellophane sheets used to overwrap the trays. The packaged flowers were offered for sale beginning the last week in May 1947 and continued through December 1948. The sale price of the packaged flowers was based on cost price of the flowers including transportation charges. To this figure was added 20 cents to cover cost of packaging, a 5 per cent loss on stock processed, and delivery cost; plus an additional 15 per cent based on sale price to pay for overhead costs and profit.

| | | |
|---|---|---|
| Example: | Flowers (total cost) | $ .95 |
| | Packaging charge | .20 |
| | | 1.15 |
| | 15 per cent mark-up | .20 |
| | Cost price to outlet | $1.35 |

This method of pricing has proven satisfactory and would permit profitable operation if sufficient volume of sales (4000 to 5000 packages a week) were maintained. An attempt was made to maintain a satisfactory grower price throughout the year on all types of cut

flowers, and prices were dropped only when gluts developed or threatened to develop.

It was the policy of the Flora Pak Research Corporation to furnish packaged flowers to the local outlets, both florist shops and supermarkets on consignment, allowing better control over the finished product. In this manner, packages which had reached the end of the recommended storage period, or had not responded properly to packaging could be removed from any outlet at any time. This also permitted following a policy of purposely oversupplying the local outlets in order to preclude the loss of any sale by providing sufficent quantity and variety of flowers in all outlets, at all times, regardless of the anticipated demand. During the experimental stage, the policy of consignment was a necessity, but in a commercial operation it is doubtful whether consignment selling would be practical, although an incentive consignment basis might be satisfactory. All out-of-town outlets handled packaged flowers on an outright purchase basis since there was no method of controlling the stock handled.

The chain outlet selected was a supermarket grocery chain that handled nationally advertised trademark merchandise and operated modern stores in all sections of the city. The packaged flowers were displayed in open-faced refrigerated cases along with other self-service items in the store. The store used a 33 to 45 per cent mark-up on cost price basis of the packaged flowers. Sales were first begun in one store of the chain and expanded to include all existing local stores by February 1948, at which time weekly advertisements were begun in conjunction with their weekly full page advertisement in the local daily papers. The supermarket outlet resulted in a satisfactory means of distribution provided the store management was interested in developing the market. Sales began slowly with a high percentage of returned merchandise, which dropped sharply in September. The number of units declined with the increased cost of stock during October through December, which in turn increased the sale price. January sales remained low due to shortage of stock. From January on roses and carnations were purchased on a contract price, and a uniform selling price with minimum fluctuations was maintained. The advertising begun in February practically doubled sales in all the outlets. Sales continued to be high during March, climaxed by Easter holiday, but dropped back again in April. Sales reached an all time high on Mother's day week-end and then began to drop steadily. Memorial day did not bring the anticipated rush of business, partially because of the long week-end with people away from home and partially because roses were practically all that was available to offer for sale. Sales dropped nearly 50 per cent the first week in June and continued to diminish until they were discontinued on July 19th. The sales figures for the month of November, February, March, and May do not accurately portray the sales potential. On Thanksgiving, Valentines day, Easter, and Mother's day, there were not enough packages available to supply the demand. For Thanksgiving all stores were sold out of flowers

from 24 to 48 hours prior to the holiday. The item in greatest demand was pompon chrysanthemums. For the latter three holidays, it was estimated that 30 to 50 per cent more roses could have been sold, although 6,000 were packaged for Valentine's day, 11,500 for Easter, and 14,500 for Mother's day. Christmas demand was not as great due to the greatly increased prices of the stock purchased for packaging. The sale price during Christmas week increased from 20 to 80 per cent on all flower items, which was more than the average consumer would pay. Flower sales dropped quite rapidly following Mother's day week-end, with the blooming of spring flowers, peonies, and the outside roses; which is interpreted to indicate that the consumers of the flowers offered in supermarket outlets were largely people with homes who had flower gardens in season and welcomed the opportunity of having cut flowers at reasonable prices during the remainder of the year. Sales records for individual stores follow quite closely the income bracket of the community in which the store is located. There were indications that this might be adjusted through proper selections of items offered in the different stores.

Three types of retail stores were selected for trial, the down-town location, the suburban greenhouse shop, and a merchandising store on a well traveled road. All three outlets sold bulk flowers at a maintained minimum price and handled the packaged flowers as a cash and carry, no-service item at a minimum mark-up, 60 per cent to 100 per cent. When service was desired, additional charges were added to cover the cost of those services performed. Sales were steady, indicating a well balanced packaged cut flower sale development. When packaged flowers were first placed in this outlet, it had been in operation approximately 9 months. The gross volume was very low and cut flower sales next to nothing. As an example, for Christmas 1946, 200 roses and 125 carnations were sold. In comparison for Christmas 1947, over 1200 packaged roses alone and 600 packaged carnations were sold. An estimated additional 600 to 800 roses could have been sold had they been available. Demand again greatly exceeded supply at Easter and Mother's day, when 900 packaged roses and 600 packaged carnations were sold at each holiday. June sales for 1948 marked a definite slump, felt quite generally in all business, but through an active advertising campaign featuring prepackaged flowers, sales have climbed remarkably in July and are holding quite steadily in August, the two low months on the sales calendar. This outlet has shown a substantial increase in sales volume and store traffic, which is credited largely to the use of prepackaged flowers.

The out-of-town outlets handled packaged flowers on an outright purchase basis. The downtown store is favorably located for transient or walk-in traffic in the business section of a city of 11,000. The greenhouse shop is located in the residential section of a city of 7,000 and has approximately 15,000 square feet of greenhouse space in conjunction with the retail store. In the latter outlet, packaged flowers were used as a supplement to their own production. Neither of these two outlets had access to local wholesale houses. Summer

periods were changed from only funeral and wedding work to a well balanced business with a brisk cut flower volume. The downtown location reported a 300 per cent increase in summer business both from the standpoint of sales and dollar volume. This increase was not due to the actual sales volume of the packaged flowers. The opinion expressed by the management was that by having the packaged flowers available they had been able to stimulate and maintain increased store traffic and thereby increase the sale of all types of merchandise, including design work, pot plants, and allied lines. The results obtained through the greenhouse shop were not as outstanding as in the other two outlets. By using the packaged flowers as a supplement to their own production, the sales volume of packaged flowers was reduced. This is borne out by the sharp drop in the average weekly sales in November. They had a heavy cut of cloth house pompons which were featured at very low prices to avoid dumping, and consequently a reduced need for packaged or other flowers. However, this store reported a definite following among their customers for packaged flowers.

All three retail florist outlets reported excellent consumer acceptance and the establishment of a definite following among customers for packaged flowers, to the point where they refused to accept anything else. Store traffic was increased, and as a result the sale of all lines of merchandise was stimulated.

The more important factors which have influenced the sale of packaged flowers in supermarkets during the past year are listed below:

1. The location and amount of display space devoted to packaged flowers. The preferred location in the average supermarket is in the fresh produce section or dairy products section where the customer takes time to shop and compare. Sufficient space is required in order to maintain a display large enough to arrest the attention of the customer for at least 5 seconds.

2. Sixty per cent of all flower sales were made during the last 2½ days of the week. Sales showed a tendency to decline during the last week of the month.

3. Flower sales decreased during traveling holidays such as July 4th and Labor Day. Reduced sales occurred during the first few days of a hot spell.

4. Killing frosts caused a decline in sales for a period of 7 to 10 days. It was believed that when frosts were predicted in this area, outdoor flowers were cut and distributed among friends and neighbors thus reducing the demand.

5. During pre-Christmas gift buying period, Thanksgiving through December 15, flower sales were very low.

6. Very sharp increases in sales were noted when items could be featured for less than a dollar.

7. There was a marked decrease in sales following a flower holiday.

There were advantages and disadvantages connected with the distribution of packaged flowers through retail flower stores. Psycho-

logically they were the best outlet for flower sales because the buying public naturally thought of the flower shop when considering flower purchases. However, in most instances they were not favorably located and did not have sufficient store traffic to stimulate impulse buying. The high mark-up and low volume type of business to which most florists conform is a distinct disadvantage to the sale of packaged flowers. Perhaps the biggest disadvantage in retail shops is their reluctance to change, in their manner of selling. Retailers have the advantage of being able to use the packaged flowers, which were not sold as such, in design work and thus prevent losses. They also should possess the knowledge of proper uses and handling of flowers. The acceptance of packaged flowers by the retailers who have cooperated in this research program has been very encouraging. At the beginning these florists accepted packaged flowers and expressed a willingness to cooperate in determining their value from the retailer's standpoint. The comments and reactions submitted after handling these flowers for the trial period include:

1. Prepackaging brings more people into the flower shop and makes regular customers out of sporadic buyers of the past. It creates a demand for flowers from a part of the public which has not been reached in the past, yet it does not reduce sale of the better grades of cut flowers.

2. Prepackaged flowers take up less storage space in the refrigerator, and lessen the amount of handling required in selling. They have a definite sales appeal to the average customer.

3. It gives the small retailer a greater variety in selection and prices of flowers at all times, thereby making it much easier for him to extend his service to a wider range of customers and to cater to all income groups.

4. This method of handling flowers eliminates without exception, bruising and breakage of flower heads. Losses are reduced to an absolute minimum due to the greater storage periods which can be maintained in addition to having the stock received in better condition.

5. The customers are better satisfied due to the better keeping qualities at more reasonable prices. Repeat sales are amazing.

## General Results in Marketing

*Flower Preference:*—The preferred flower, throughout, was the rose, followed closely by flowers in season such as pompons, gladioli, and bulbs. Carnations were generally a less popular sales item, particularily in supermarkets. Gardenias were excellent when sold at feature prices.

*Color Preference:*—Color varied with different flower types. Roses—straight colors preferred; two color mixtures sold well; red was best except during extreme hot weather when the cooler shades of pink and yellow were in demand. Pompons—mixed colors preferred, with sharply contrasting colors selling best. Carnations—mixed and straight colors evenly divided. Gladioli—straight colors preferred.

*Number Preference:*—Units of dozens and half dozens were preferred over odd numbers of flowers where a choice was provided, although indications pointed to satisfactory sales for odd numbers when that was all that was offered.

*Quality and Grades:*—Poor quality flowers met with reduced sale. The shorter or lesser grades were best sold through the supermarkets and better grades through the retail flower shops. In either case, the quality was maintained regardless of the sales outlet employed.

*Differential Packages:*—There developed a definite need for complete differentiation and distinction between packages sold through supermarkets and those through retailers, especially so when the two outlets were located in the same community.

*Pricing and Price Fluctuation:*—To develop and maintain a sizable packaged cut flower volume, prices must be fairly well stabilized throughout the year. Fluctuations during scarce and peak production are necessary but these price changes must be held to a minimum. Sharp increases placed flowers beyond the means of the class of consumers that prepackaging is attempting to develop.

*Buying Habits:*—During the past year a series of surveys was conducted in order to obtain more definite knowledge of the buying habits of the general public. Questionnaires were sent to representative retail florist shops throughout the country in which the retailers were asked to report the breakdown of gross business into the various types of sales. The result of this survey indicated that in the average florist shop 60 to 65 per cent of the total was composed of funeral work, 20 to 25 per cent special occasion buying, with the remaining 10 to 20 per cent made up of miscellaneous sales such as hospital work, supplies, and so on. One of the most important features of this survey was the disclosure that only 2 to 3 per cent of the gross sales was composed of people who bought flowers for their own use at home.

At the same time another survey was conducted by submitting questionnaires directly to the buying public to determine the pattern of buying for the average citizen. This survey showed that 68 per cent bought flowers only on special occasions or for funerals, 25 per cent bought flowers two or three times a year, and less than 3½ per cent as regularly as weekly or monthly. When asked the reasons for not buying more often, 82 per cent indicated that flowers from the average florist were too expensive and beyond their means. Prepackaging was described to these people and it was explained how and why packaged flowers might be sold at more reasonable prices. They then indicated that if these flowers were conveniently available, 48 per cent would buy as regularly as weekly or monthly, with 10 per cent buying two or three times a year and 40 per cent continuing with special occasion buying. In other words, in this representative sample of the buying public, there were 40 per cent of the people whose flower buying habits cannot easily be changed. However, the shift toward more regular flower buying among the remaining 60 per cent represents a tremendous potential for increased flower sales.

At intervals during the course of the marketing problem, records

were kept on 12 to 15 per cent of individual sales and personal contacts were made with the purchaser of packaged flowers. This proved very encouraging, with excellent consumer acceptance being established through both types of selling outlets. On the basis of this marketing report, prepackaging flowers has contributed a means by which cut flowers can reach the consumer in better condition and at less cost than the present means of distribution allows. Distribution can be handled quite satisfactorily through both retail flower shops and supermarket outlets.

## Literature Cited

1. Hauge, A., Bryant, W., and Laurie, Alex. Prepackaging of cut flowers. *Proc. Amer. Soc. Hort. Sci.* 49: 427–432. 1947.

# Effect of Waters of Different Quality on Some Ornamental Plants[1]

By HAROLD E. PEARSON, *Metropolitan Water District, La Verne, Calif.*

ORNAMENTAL plants grown in semi-arid climates or in greenhouses are occasionally affected by the chemical characteristics of the water used for irrigation. The range of tolerance to soil salinity and alkalinity caused by irrigation water is probably greater for the many species of ornamentals than for crop plants. Some work on the effect of water quality on ornamentals has been reported (8, 10) but there is a need for additional study in this field.

Commercial and amateur growers have observed that a change of water supply sometimes requires new cultural techniques. In order to assist growers in developing improved cultural practices when using Colorado River Aqueduct water, the Metropolitan Water District of Southern California in 1942 initiated studies to determine the sensitivity of several ornamental plants to saline and alkaline soils. Begonias and azaleas were selected for study because of difficulties reported by growers within a few months after the use of treated Colorado River water. Although the response of a number of popular annual and perennial ornamentals to several types of water has been compared, the present discussion is limited to observations on the growth of begonias, azaleas, fuchsias, camellias, boxwood, and chrysanthemums.

## MATERIALS AND METHODS

The response of plants to three types of irrigation water was of primary interest in these experiments: 1, well waters containing about 250 parts per million (ppm) dissolved solids, Table I: A, B, and C; 2, natural Colorado River water, D, a high calcium water containing 750 to 800 ppm dissolved solids; and 3, treated Colorado River water, F and G, a water having a high sodium percentage. The method of softening and the reasons for softening Colorado River water for domestic and industrial uses has been described elsewhere (6, 9). The normal treatment from 1942 to 1947 has produced a water in which sodium represents 77 to 84 per cent of the total cations (6, Table I). The effect of partial softening and complete zeolite treatment, E and I, was also observed, and a special soft water, H, was prepared in which 1.5 m e per liter of potassium replaced part of the sodium. Water J containing 450 to 500 ppm of dissolved solids was produced by an electrolytic method being investigated by the District

[1]The Metropolitan Water District is under the direction of Julian Hinds, General Manager and Chief Engineer. The interest and encouragement of R. B. Diemer, Chief Operation and Maintenance Engineer, and W. W. Aultman, Water Purification Engineer, is acknowledged.

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as a possible means of improving the quality of treated Colorado River water.

Conventional propagation methods were employed to study the effects of waters C, D, and F, on cuttings placed in sand and a mixture of 1:1 peat and sand both with and without the use of Hormodin powders. A minimum of 10 cuttings was used for each combination of treatments.

TABLE I—ANALYSIS OF IRRIGATION WATERS STUDIED

| Number | pH | Milli-Equivalents Per Liter | | | | | | | Per Cent Na* | Electrical Conductivity EC×10[6] | Total Solids (Ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na+K | $CO_3$ | $HCO_3$ | $SO_4$ | Cl | | | |
| A | 7.5 | 1.90 | 0.66 | 0.96 | 0 | 2.54 | 0.44 | 0.23 | 27 | 360 | 218 |
| B | 7.9 | 1.14 | 1.19 | 1.57 | 0 | 2.37 | 0.80 | 0.73 | 40 | — | 225 |
| C | 7.1 | 1.05 | 0.66 | 3.00 | 0 | 2.51 | 1.12 | 1.07 | 64 | 380 | 276 |
| D | 8.2 | 4.69 | 2.79 | 5.35 | 0 | 2.36 | 7.63 | 2.82 | 42 | 1260 | 798 |
| E | 8.3 | 2.97 | 1.80 | 8.11 | 0 | 2.35 | 7.67 | 2.85 | 63 | — | 810 |
| F | 8.5 | 1.25 | 0.82 | 10.88 | 0.13 | 2.30 | 7.68 | 2.85 | 84 | 1400 | 838 |
| G | 9.6 | 1.20 | 0.58 | 9.96 | 0.57 | 0.20 | 7.78 | 3.21 | 85 | — | 779 |
| H | 8.3 | 1.23 | 0.84 | 10.88† | 0 | 2.37 | 7.68 | 2.89 | 84† | — | 854 |
| I | 8.0 | 0.05 | 0.15 | 12.70 | 0 | 2.36 | 7.68 | 2.85 | 98 | 1420 | 837 |
| J | 7.4 | 1.55 | 1.40 | 5.31 | 0 | 1.38 | 5.14 | 1.75 | 64 | 880 | 526 |

*Sodium expressed as a percentage of the total cations.
†1.5 me per liter of potassium substituted for sodium. Normal Colorado River water contains 0.08 me per liter potassium. Water A also contained 0.29 me per liter nitrate ion; the others contained only traces of nitrate.

Plants obtained from the propagation experiments were potted and used for the subsequent studies to determine the effect of the different irrigation waters on plant growth. Plants for the begonia and azalea experiments, which were initiated prior to the propagation work, were selected from uniform nursery stock in 4-inch pots. In all cases plants were shifted into larger pots as required. An equal amount of irrigation water was applied to each pot containing a similar variety of plant, the amount depending on weather conditions and the size of the plant. Yields were based on the dry weight of the tops except in the case of the camellia in which total stem length and number of leaves were used as the measure of growth. Four replicate plants were used to obtain the average yield for each treatment in the begonia experiment, and eight were used in the other observations.

In 1941 when Rex begonias irrigated with treated waters, F and G, began to show leaf-burn, the rapid response suggested causes other than increased soil salinity *per se*. The practice of sprinkling the foliage once or twice daily to raise the relative humidity of the air had been observed to produce marginal burning of older leaves, but it was not severe in most cases (1,11). In order to observe whether sprinkling of the more saline waters on the foliage of Rex begonia would increase the tendency toward leaf-burn, one set of plants was irrigated by sprinkling some water on the foliage and another set was surface watered without wetting the foliage.

## RESULTS

*Propagations:*—Rooting of cuttings was equally satisfactory with waters C, D, and F for all of the varieties tested: leaf cuttings from

*Begonia Rex-culturum*, *B. Ricinifolia*, and *B. bunchii*, and stem cuttings of *Buxus japonica*, *Camellia japonica* var. Pink Perfection, several fuchsias, Jupiter, G. Monk, and *F. lycoides*, and chrysanthemum. The saline content of the rooting media was almost proportional to the salinity of the waters used, and it was not high in any case. The waters having the higher sodium percentages, C and F, caused the pH of the sand to increase to 8.5 to 9.0 in cases where the rooting period was lengthy, for example, boxwood and camellia. The plaster sand contained a small amount of clay and the hydrolysis of the adsorbed sodium on the clay probably caused the high pH. Since the degree of dispersion of the clay will increase with each re-use, it is important to use very clean sand when propagating with high sodium waters. While the more progressive growers use fresh sand for each batch of new cuttings, there are some who re-use the same sand several times before replacement. The addition of acid peat counteracts any adverse effects of this dispersion by controlling the pH of the medium. Although Hitchcock (5) has recommended a 1:1 sand-peat mixture, the proportion of sand to peat probably might be increased to 2:1 for some species since these tests indicate that excessive moisture sometimes occurs with a 1:1 mixture.

To study the effect of increasing salt content upon the rooting of fuchsia cuttings, sodium chloride was added to waters D and F to increase the total dissolved solids to approximately 1200, 1500, and 2000 ppm. More than 90 per cent of the cuttings rooted with these more saline waters. However, the number and vigor of the roots in the sand medium decreased as the concentration of salts in the water increased, and some leaf abscission occurred. The cuttings rooted in the sand-peat moss mixture were less affected by the more saline waters than those in straight sand. Since fuchsia cuttings root somewhat more readily than cuttings from some other species, the writer believes that waters containing 1500 to 2000 ppm of salts may not be generally suitable for propagation work.

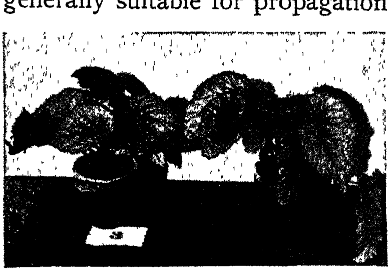

FIG. 1. Response of Rex begonia to sprinkling with water G; sprinkled plant on left, surface watered on right.

*Begonias*:—During the first 3 months, water quality did not appear to influence the growth of the Rex begonias in the surface watered series. All of the sprinkled plants showed some marginal burn which made the plants appear less thrifty and less attractive, as illustrated in Fig. 1. As the greenhouse temperatures became warmer in the summer months, all of the sprinkled plants showed a greater amount of leaf burning, irrespective of the waters used. Temperatures were somewhat above the optimum for these tender plants, and some of the burned leaves died before harvesting. The order of increased burning with the different waters was B, D, F, and G. The actual weight of the plants produced is expressed

on a percentage basis using the plants surface watered with water B as the index (Table II). Plants sprinkled with D were in the most unfavorable location with regard to humidity and temperature; therefore, the yield figures may be somewhat low.

TABLE II—EFFECT OF WATER QUALITY ON GROWTH OF SOME ORNAMENTALS

| Growth Observed as a Percentage of Underlined Index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type of Water | | A or B | D | E | F | G | H | I |
| Plant | Irrigation Time | | | | | | | |
| Begonia Rex, Crimson Glow | | | | | | | | |
| Surface watered | 7 months | *100* | 60 | — | 53 | 54 | — | — |
| Sprinkled | 7 months | 56 | 44 | — | 62 | 47 | — | — |
| *Fuchsia*, Jupiter | 6 months | *100* | 90 | 90 | 90 | — | 100 | 75 |
| *Camellia japonica*, Pink Perfection | 1 year | *100* | 84 | — | 88 | — | 85 | — |
| *Camellia japonica*, Pink Perfection. | 2 years | *100* | 78 | — | 58 | — | — | — |
| *Buxus japonica* | 1 year | *100* | 98 | 99 | 101 | — | 94 | 87 |
| *Buxus japonica* | 15 months | *100* | 110 | — | 92 | — | — | — |
| Chrysanthemum | 5 months | *100* | 92 | 92 | 89 | — | 92 | 85 |

The mineral analyses of the leaves indicate that the chloride ion is absorbed readily by Rex begonias. A correlation between the concentration of salts in the soil and the chloride content of the leaves is indicated in fig. 2. High chloride absorption facilitates the absorption of bases and this may be observed for potassium and magnesium (Table III). Calcium was not determined because whitewash was accidently sprayed on some of the foliage while painting the glass house. Sulfate was also absorbed in greater quantities as the salinity of the soil increased between the 3- and 6-month sampling. When comparing the chloride, sulfate, and sodium content of the sprinkled and surface watered plants irrigated with the same water, some differences may be noted. Generally, the chloride and sulfate absorption was higher in the case of the sprinkled plants; the sodium content was almost doubled.

This extra absorption of sodium, chloride, and sulfate in the sprinkled series may account for the leaf burn. A detached wilted Rex leaf will become turgid within an hour if a few drops of water are sprinkled on it. Since the leaves were thoroughly washed with distilled water prior to analysis, the greater mineral content of the sprinkled leaves indicates that some absorption of salts occurs as water moves into the leaf. The general higher level of soil salinity reflected in the higher potassium, chloride, and sulfate levels in the leaves collected after 6 months may also be a contributing factor toward leaf-burn.

The rhizomatous *Begonia Ricinifolia* grown under the same conditions as the Rex begonia showed no marginal leaf burn nor growth depression as a result of sprinkling. The plants produced with the low salinity water B were slightly larger than those watered with D; plants watered with F and G were less thrifty than the other two

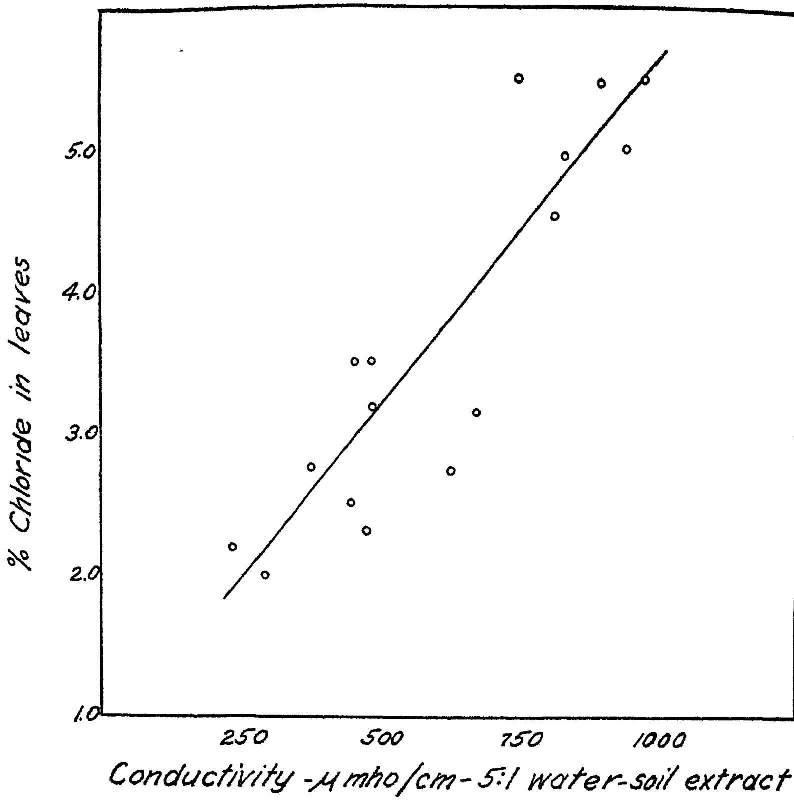


FIG. 2. Correlation of salt concentration in soil with chloride content of Rex begonia leaves.

groups; but no difference was observed for the waters at pH 8.4 and 9.6.

*Azaleas:*—The problem of selecting a suitable variety of ornamental plant for study was apparent in observations on azalea response to water quality. In the first experiment, a group of 1-year-old Kurume azaleas, Pink Beauty, was watered with waters A, D, F, water F acidified to pH 6.0, and distilled water. After 1 year of treatment, a photograph of representative plants was taken (Fig. 3). Sprinkling was not conducive to leaf-burn and growth through the year was normal. With the spring flush of growth in 1943, the more saline waters produced a more bushy compact plant than the low saline or distilled water.

Later observations of more than 100 azalea varieties being grown under identical conditions with a blend of waters A and F containing 550 to 700 ppm of dissolved solids showed some interesting varietal differences after a 5-month irrigation period. Only one *Azalea indica* variety of a large number of varieties showed any leaf tipburn or other

TABLE III—EFFECT OF WATER QUALITY ON MINERAL CONTENT OF THE PLANT

| Treatment | Percentage (Based on Dry Weight of Leaves) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ca | Mg | K | Na | Cl | S | P |
| *Begonia Rex, After 3 Months Irrigation* | | | | | | | |
| Surface watered with | | | | | | | |
| B | — | — | 2.76 | 0.12 | 1.99 | 0.29 | — |
| D | — | — | 3.04 | 0.17 | 3.17 | 0.31 | — |
| F | — | — | 2 96 | 0.28 | 2.27 | 0 28 | — |
| G | — | — | 2.86 | 0.25 | 2.48 | 0.27 | — |
| Sprinkled, water | | | | | | | |
| B | — | — | 2.52 | 0.32 | 2.19 | 0.33 | — |
| D | — | — | 2 63 | 0.48 | 3.46 | 0.37 | — |
| F | — | — | 2.38 | 0.71 | 2.75 | 0.33 | — |
| G | — | — | 2.96 | 0.86 | 3.49 | 0.39 | — |
| *Begonia Rex, After 6 Months Irrigation* | | | | | | | |
| Surface watered with | | | | | | | |
| B | * | 0.53 | 3.77 | 0.19 | 2.72 | 0.48 | 0.41 |
| D | * | 0.73 | 4.73 | 0.24 | 4.98 | 0.65 | 0.45 |
| F | * | 0.64 | 5.10 | 0.45 | 5.43 | 0.67 | 0.46 |
| G | * | 0.71 | 4.95 | 0.42 | 5.45 | 0.63 | 0.50 |
| Sprinkled, water | | | | | | | |
| B | — | 0.55 | 3.92 | 0.24 | 3.08 | 0.59 | 0.52 |
| D | — | 0.85 | 4.73 | 0.41 | 5.46 | 0.68 | 0.48 |
| F | — | 0.65 | 3.99 | 0.90 | 4.54 | 0.68 | 0.48 |
| G | — | 0 68 | 4.28 | 0.70 | 4.90 | 0.58 | 0.45 |
| *Fuchsia, Jupiter, After 10 Months Irrigation* | | | | | | | |
| Water | | | | | | | |
| A | 1.78 | 0.50 | 4.62 | 0.25 | 0.10 | 0.28 | 0.23 |
| D | 1.30 | 0 50 | 2.80 | 0.68 | 0.30 | 0.45 | 0.23 |
| F | 1.04 | 0.38 | 4.61 | 0.63 | 0.50 | 0.50 | 0.24 |
| *Camellia japonica, After 20 Months Irrigation* | | | | | | | |
| Pink Perfection, water F | 0.98 | 0.23 | 1.68 | 1.71 | 1 61 | 0 54 | 0.18 |
| Rosita, water F | 1.05 | 0.28 | 1.63 | 1.96 | 1.53 | 0.67 | 0.17 |
| *Buxus japonica, After 12 Months Irrigation* | | | | | | | |
| Water | | | | | | | |
| C | 1.53 | 0 37 | 1.17 | 0.05 | 0.39 | 0.25 | 0.57 |
| D | 1.56 | 0.38 | 1.00 | 0.11 | 0.47 | 0.15 | 0.56 |
| E | 1.33 | 0.34 | 1.07 | 0.20 | 0.50 | 0.17 | 0.50 |
| F | 1.34 | 0.32 | 0.99 | 0.28 | 0.43 | 0.16 | 0.49 |
| H | 1.25 | 0 29 | 1.16 | 0.24 | 0.45 | 0.16 | 0.44 |
| I | 1.09 | 0.29 | 0.98 | 0.38 | 0.49 | 0.19 | 0.43 |

*Other leaf samples of this begonia in absence of whitewash contained 3 to 4 per cent calcium.

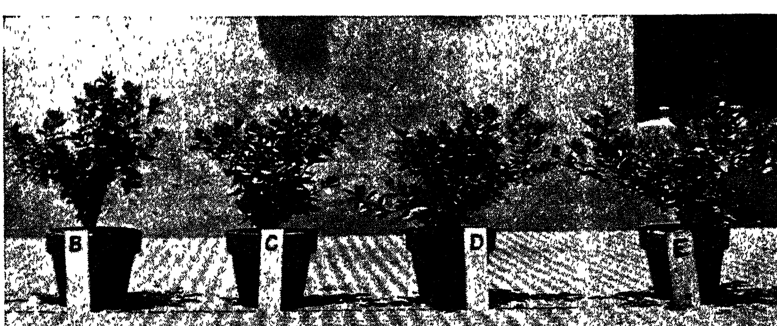


FIG. 3. Azaleas grown with different waters for 1 year. Left to right: water F; water F with pH reduced to 6.0; distilled water; and water B, a low saline water.

symptoms of saline injury. About half of the Kurume varieties showed some tipburn, although it was slight in some cases.

The more hairy-leafed azaleas may be injured by moderately saline waters because of sprinkling as in the case of the Rex begonias. However, the explanation of the varietal differences to soil salinity appears to be associated with root structure and habit. Many of the Kurume azaleas produce a multitude of fine hair-like roots which often become massed at the wall of the porous clay pots in which they are usually grown. *Azalea indica* ordinarily have coarser roots which are distributed more evenly through the soil, that is, they do not become root-bound as rapidly as the Kurume types. Reasons for the deleterious effect of soil salinity on root-bound plants will be discussed later.

Three types of water, A, F, and J were used to irrigate the azalea, Avalanche, for a period of 7 months, January to August. The plants in group A and J showed no visible signs of injury, but those irrigated with water F showed some evidence of leaf burn. The dry weight of eight plants produced with each water was: A–62.8 grams; J–44.2 grams; and F–34.2 grams. These data indicate that some growth depression has occurred with a water containing only 500 ppm soluble solids even though visible evidence of injury was lacking.

*Fuchsias:*—Those plants irrigated with waters A and D grew with equal vigor, or, if slight differences could be observed the more saline, high calcium water (D) produced better plants than A. The plants in group F lagged behind the others. After shifting to gallon cans, the fuchsias grew rapidly. The delay in top growth while the plants were young in the case of the high sodium waters F, H and I seemed to be due to a slower rate of root growth. It has been noted that the roots of potted plants watered with the high-calcium waters usually extend throughout the soil mass. With the high sodium waters the roots are usually less vigorous and occur more in the upper two-thirds of the pot. Whether this difference in roots is due to a subnormal nutritional level of calcium or unfavorable soil structure because of sodium dispersion cannot be stated with certainty. With these highly organic soils the former effect is probably more in evidence.

After 2 months in the gallon cans there was little difference in the plants watered with A, D, E, F. The potassium containing water H stimulated better growth than water F. The recovery made it difficult to observe differences between the plants watered with 60 and 80 per cent sodium waters. Two of the plants watered with the 100 per cent Na water (I) died within 30 days and the others were retarded. In general, the fuchsias are less sensitive to soil salinity than many other shade-loving plants. Foliar analysis did not show any striking differences, but did show somewhat greater amounts of sodium, chloride, and sulfate in plants watered with the more saline waters.

*Camellias:*—The data for the Pink Perfection variety of *Camellia japonica* indicate that a considerable time must elapse before growth depression due to soil salinity becomes apparent. No leaf burn as a result of soil salinity occurred until the third year at which time the plants were beginning to become rather root-bound in 6-inch pots. Plants moved into larger pots or into the soil before showing exces-

sive leaf burn usually recover from the effects of previous saline accumulations. The mineral composition of Pink Perfection and Rosita leaves after slight burning appeared is shown. It may be noted that both chloride and sodium ions are absorbed in rather large quantities. The camellia studies are being continued.

*Others:*—Chrysanthemum and boxwood showed only slight response to differences in water quality. Healthy vigorous plants were produced with all the waters. The 98 per cent sodium water (I) caused earlier bloom in the chrysanthemum and early dormancy following blossoming. The 80 per cent sodium water (F) caused earlier bloom but no speeding up or dormancy. While on a weight basis little difference could be observed in the total growth of boxwood, there was a considerable tendency for the high sodium waters F and I to cause a more compact bushy growth. The potassium water H also produced this effect. Perhaps this effect may be correlated with the decreased calcium uptake indicated by the leaf analysis in Table III.

*Effects on Soils:*—Soil tests have been made during these experiments even though a correlation between soil conditions and plant response is occasionally difficult. Frequently soil salinity will increase markedly before visible symptoms appear in the plant (3). Conversely, in potted culture work, the use of a little extra water may cause leaching of salts from the pot; then, the soil analysis may indicate a lower level of salinity than the plant symptoms suggest.

In the begonia test the Colorado River waters D, F, and G caused a doubling of the salt content of the soil in 3 months (Table IV). After

TABLE IV—EFFECT OF WATER QUALITY ON SOILS USED FOR GROWING ORNAMENTAL PLANTS

| Type of Water | | | | B | D | F | G | H | |
|---|---|---|---|---|---|---|---|---|---|
| Plant and Measurement | Ratio Water-Soil Extract | Irrigation Time (Months) | Original Soil | | | | | | |
| Begonia Rex | | | | | | | | | |
| pH | 5:1 | 3 | 7.3 | 7.3 | 7.5 | 7.3 | 7.7 | — | |
| EC×10⁶ | 5:1 | 3 | 197 | 292 | 478 | 472 | 441 | — | |
| Per cent Na | 5:1 | 3 | 66 | 47 | 38 | 75 | 76 | — | |
| Begonia Rex | | | | | | | | | |
| pH | 5:1 | 6 | — | 7.5 | 7.3 | 7.6 | 7.5 | 6.9 | |
| EC×10⁶ | 5:1 | 6 | — | 621 | 949 | 731 | 900 | 791 | |
| Per cent Na | 5:1 | 6 | — | 55 | 39 | 79 | 77 | 77 | |
| Type of Water | | | | A | D | F | J | | |
| *Azalea*, Avalanche | | | | | | | | | |
| pH | 10:1 | 6 | 4.3 | 4.2 | — | 4.0 | 4.1 | | |
| EC×10⁶ | 10:1 | 6 | 142 | 1680 | — | 2840 | 1950 | | |
| Per cent Na | 10:1 | 6 | 80 | 75 | — | 85 | 86 | | |
| *Fuchsia*, Jupiter | | | | | | | | | |
| pH | 2:1 | 18 | — | 7.6 | 7.7 | 7.8 | — | | |
| EC×10⁶ | 2:1 | 18 | — | 1260 | 1480 | 1470 | — | | |
| Type of Water | | | | C | D | E | F | H | I |
| *Fuchsia*, Jupiter | | | | | | | | | |
| pH | 2:1 | 6 | — | 5.0 | 4.9 | 5.3 | 4.8 | 5.0 | 5.1 |
| EC×10⁶ | 2:1 | 6 | — | 1950 | 2440 | 2370 | 2310 | 2560 | 2290 |
| Per Cent Na | 2:1 | 6 | — | 9 | 11 | 18 | 20 | 16 | 16 |
| *Buxus japonica* | | | | | | | | | |
| pH | 2:1 | 12 | — | 4.9 | 4.5 | 4.8 | 4.7 | 5.1 | 5.2 |
| EC×10⁶ | 2:1 | 12 | — | 1270 | 1860 | 1550 | 1470 | 1370 | 1110 |
| Per cent Na | 2:1 | 12 | — | 9 | 17 | 17 | 27 | 28 | 36 |

6 months the soluble salts trebled in the soil irrigated with the low saline water B; during the same time the Colorado River waters caused the dissolved solids to increase to about four and one half times the original amount present. Although no effort was made to leach the soil, there was undoubtedly some drip through the bottom of the pots. Leaching accounts for the low levels of salts in the fuchsia and boxwood soils after long periods of irrigation. In the Avalanche experiment where no effort was made to leach the peat, the soluble salt content of the medium increased 20 times in 7 months with the more saline water F. Conscious leaching of peat by irrigation can reduce the salinity of the medium, but the use of a larger volume of water is required because of the high water holding capacity of peat.

The evaluation of the effects of the soluble salt content of water extracts on plant growth depends on a knowledge of the water holding-capacity of the soil and the moisture content at the wilting point. Considerable progress has been made on such studies for soil low in organic matter at the United States Regional Salinity Laboratory (2). The determination of these moisture levels for highly organic soils and the correlation of soil solution concentrations is a problem of considerable interest to nurserymen. Water extracts showing conductivity readings equivalent to 2000 ($ECx10^6$) for 2:1 water to soil ratios and 800 for 5:1 ratios are considered to be excessive by Fisher (4). In some cases the data in Table IV fall within these limits, but in other cases the need for considering the field moisture capacity of the soil is apparent. For example, the field moisture content of the begonia soil was 12.5 per cent, whereas, the azalea soil had a field moisture capacity of over 200 per cent on the dry weight basis. Thus, the soil solution concentration was actually higher in the begonia soil than in the azalea peat.

The effect of the high sodium waters on the soil solution and colloid dispersion was of considerable interest in this study. In the begonia experiment, the sodium percentage of the water extract tended to approach the sodium percentage in the irrigation water. Low sodium percentages were observed for the fuchsia and boxwood soils with all waters at the time of testing. These soils contained more organic matter than the begonia soil. In addition, a balanced liquid fertilizer was applied to these soils at 3- to 4-week intervals while uramon was the only fertilizer added in the begonia experiment. Apparently, the fertilizer added to the fuchsia and boxwood soils caused an increased amount of soluble calcium in the extract. This suggests a means of controlling high sodium ratios by the use of fertilizer materials and organic matter. Little significance is attached to the high sodium ratios observed for the azalea peat irrigated with both low and high sodium waters because the acid peat absorbs considerable amounts of calcium and magnesium in exchange for hydrogen ions but it absorbs sodium to a lesser extent. Some dispersion of the clay in the potting soils was noted for those irrigated with 80 and 100 per cent sodium waters, but the presence of organic matter precluded any observable effects on soil permeability to air or water.

## Discussion

These experiments support the suggestion of Wall and Cross (10) that waters containing 500 ppm of total dissolved solids are likely to cause reduced growth only with the more salt-sensitive plants or under unfavorable conditions of temperature, light, and humidity. They also found that waters containing 1000 ppm can generally be used satisfactorily, but the kinds of salts present and their quantities must be considered. In this study the waters containing approximately 800 ppm of total salts, principally sulfates, were satisfactory for growing some types of begonia, fuchsia, camellia, boxwood and chrysanthemum, but they caused trouble with some azalea varieties and Rex begonia. High sodium waters were less desirable than high calcium waters. However, except for the camellia after 2 years in the same pot, the growth on the basis of weight was not markedly different for the high sodium waters until the sodium percentage was greater than 80. Both the 80 and 100 per cent sodium waters exhibited a tendency to cause a more compact, bushy growth habit.

Wall and Cross (10) have outlined several points to observe when growing ornamental plants with moderately saline waters: 1, Water more heavily, and not so often. 2, Keep the soil as moist as possible without retarding plant growth. 3, Use a heavy type of soil containing considerable organic matter. 4, Keep the temperature lower and the humidity higher than would be done with low saline waters. 5, Select varieties which are most tolerant to the type of water being used. A few suggestions might be added to these. In the process of leaching to control soil salinity, the fertility level of the soil may be reduced. Slowly available nitrogen sources, such as cottonseed meal, legume straw, bone meal, fish meal, or tankage, have been observed to maintain soil fertility more easily under this regime of watering than do the soluble fertilizers. Soluble fertilizers are unsatisfactory unless used frequently in small dosages.

The maintenance of adequate calcium reserves for supplying the nutritional requirements of the plant and preventing soil dispersion is desirable when irrigating with high sodium waters. Even the acid-loving plants absorb considerable amounts of calcium (Table III), and root growth is more vigorous in soils with a high calcium status. Of several amendments tested, calcium sulfate and superphosphate applied to the soil or added to the water were beneficial to plant growth. Saturated solutions of gypsum were observed to be harmless to primula, carnation, and poinsettia (10), and although gypsum has been applied to a number of ornamental plants by the author, the only plants apparently showing an unfavorable response were some epiphytic orchids and azaleas.

Since the distribution of salts in a porous clay pot is not uniform, cultural practices may be modified to take advantage of this fact. The soil solution concentration is often 30 to 60 per cent higher at the walls of the pot than at the center. Knight (7) observed that fertility levels were higher at the walls of leached pots, but the difference was not as great as observed here for saline accumulations. By shifting plants into larger containers before they become badly root-bound, the major-

ity of the roots will be feeding in the least saline part of the soil. The use of non-porous pots is also recommended since approximately half of the water added to porous pots is lost by evaporation through the walls intensifying the salinity problem. This excessive loss of water can also be minimized by plunging porous pots into straw, shavings, or other moisture-holding insulating materials. This is especially important for young plants in small pots.

## Summary

The growth of a variety of ornamental plants including begonias, azaleas, camellias, fuchsias, chrysanthemum and boxwood has been studied using irrigation waters of different chemical characteristics.

The propagation of plants in sand or sand-peat medium was not affected by the waters studied. In the case of poorly washed sand, the pH of the medium tended to rise after irrigation with the high sodium waters.

Of the plants studied, Rex begonias and azaleas showed marked sensitivity to saline accumulations under potted cultural conditions. Considerable varietal difference within the same species was observed. Rex begonia leaves were particularly sensitive to burning when sprinkled with low or moderately saline waters.

Cultural suggestions for controlling salinity and alkalinity in pot culture are offered.

## Literature Cited

1. Bailey, L. H. Standard Cyclopedia of Horticulture, 3 Vols. MacMillan Co., New York. 1947.
2. Diagnosis and Improvement of Saline and Alkali Soils. L. A. Richards, Editor. U. S. Regional Salinity Laboratory. 1947.
3. Eaton, F. M. Salinity of irrigation water and injury to crop plants. *Calif. Citrograph* 20: 302. 1935.
4. Fisher, C. W. Soil conductivity tests. *N. Y. State Flower Growers', Bul.* 31. 1948.
5. Hitchcock, A. E. Effect of peat moss and sand on the rooting response of cuttings. *Bot. Gaz.* 86: 121. 1928.
6. Huberty, M. R., and Pearson, H. E. Irrigation of citrus orchards with waters of different chemical characteristics. A progress report. *Proc. Amer. Soc. Hort. Sci.*
7. Knight, A. T. Studies of pot-binding of greenhouse plants. *Mich. Agr. Exp. Sta. Bul.* 191. 1944.
8. Krone, P. R., and Weinard, F. F. Experiments with solutions of chlorine and sodium chloride on pot plants. *Proc. Amer. Soc. Hort. Sci.* 27: 444–8. 1930.
9. Montgomery, J. M., and Aultman, W. W. Water softening and filtration plant of the Metropolitan Water District of Southern California. *Jour. A. W. W. A.* 32: 1. 1940.
10. Wall, R. F., and Cross, F. B. Greenhouse studies of the toxicities of Oklahoma salt contaminated waters. *Okla. Agr. Exp. Sta. Tech. Bul.* T–20. 1943.
11. Ziesenhenne, R. Water, III. *The Begonian* 9: May, 1942.

# Delayed Incompatability of a Live Oak-Post Oak Graft Union

By W. D. ARMSTRONG, *University of Kentucky, Princeton, Ky.*, and F. R. BRISON, *A. & M. College of Texas, College Station, Tex.*

It is known that species of oaks can be successfully grafted. Little information, however, is available on the compatability of the different species. Armstrong (1) found that live oak on post oak would make a union, but observed further that "several years will be required to test the nature of the union and see whether it is only temporarily successful". Flory and Brison (3) report that a live oak-overcup hybrid united satisfactorily with post oak forming an apparently strong union and that the scions made vigorous initial growth.

A large native post oak (*Quercus stellata,* a deciduous species) growing near College Station, Texas, was partially topworked with live oak (*Q. Virginiana,* an evergreen) in the spring of 1929. The grafting was done by the senior author in working out a thesis problem under the direction of the junior author (1). Only one of three or four grafts grew at that time on this tree however, a number of; other successful grafts were made on smaller trees. A second successful graft was made on the large tree 4 or 5 years later. Several post oak limbs of the original tree were never grafted. These have continued to grow and are normal at the present time.

The original graft was made on a limb about 2 inches in diameter. It united and made what appeared to be normal growth for about 16 years. In the meantime it had grown to be about 7 inches in diameter. Beginning about that time it was observed that the foliage was sparse and many of the small limbs were dying. Examination revealed a break in the line of union between the stock and scion around most of the circumference of the limb. There were places, radially from the point of the original insertion of the graft, where vascular connec-

FIG. 1. A longitudional section of 19-year-old live oak graft on post oak. Vascular connections were made for the first 6 or 7 years of growth. This is evident in the center in contrast to the breaks in the line of union on each side.

FIG. 2. Longitudional section through a small live oak graft on post oak stock. Note that breaks have recently occurred in the union.

tions between the stock and scion were still being initiated by the continuous cambium.

This past summer (1948) the large live oak branch (now 19 years old) was practically devoid of foliage and most of the small limbs had died. The smaller limb which was grafted several years later was still normal in appearance, though as indicated later, breaks had recently occurred in the union. The large branch was cut off and radial and tangential slabs were made through the line of union with a pruning saw. These sections and records of the original graft indicate (a) that the graft united with the stock and the two continued growth until both were 2 or 3 inches in diameter; (b) that the tissues initiated by the continuous cambium layer which provided vascular connections between stock and scion were located largely at points radially from the place where the original graft was inserted; (c) that when the graft was about 6 or 7 years old, breaks began to occur in the union between stock and scion; and (d) that tissues produced laterally or tangentially by the stock below and the scion above did not unite readily even though the two were pressed closely together.

It is evident that at least six breaks occurred along one radius of the big graft union, and furthermore that each, except the last one, did grow over. This overgrowth conceivably could have resulted (a) from the reuniting of parenchyma tissue from stock directly below and scion directly above the break, or (b) by the tangential growth and ultimate union of tissues from either side of the break, as described by Bradford and Sitton (2) for the pear on quince. In either case, it is apparent that the processes did not occur readily, and that finally the graft union became completely girdled despite the close contact and even alignment of the cambium layers of scion and stock.

Several sections of this graft union and also of the younger graft in which the breaks were just beginning to occur, were made on a sliding microtome for the purpose of determining cause of the breaks in the union. From these sections, it is clearly evident that at least the phloem fibers were continuous across the graft union after the break had definitely occurred in the xylem. It is also indicated that the xylem of the post oak became differentiated at times when there was no corresponding differentiation of the xylem of the live oak immediately above, a condition also observed by Bradford and Sitton (2). Nevertheless the two components have grown at about the same rate without noticeable overgrowth above

FIG. 3. The larger center limb is a 19-year-old live oak graft on post oak. The foliage is sparse and many of the small limbs are dead.

or below the union. One possible explanation is that the initial breaks may have been caused by slower rate of xylem formation by the scion and the break created a girdling effect which compensated by stimulating increased growth of the scion.

LITERATURE CITED

1. ARMSTRONG, W. D. Unpublished Thesis, A. & M. College of Texas. 1929.
2. BRADFORD, F. C., and SITTON, B. G. *Mich. Agr. Exp. Sta. Tech. Bul.* 99: 72–78. 1929.
3. FLORY, W. J., and BRISON, F. R. *Tex. Agr. Exp. Sta. Bul.* 612. 1942.

# Crabgrass Control in Turf With Chemicals[1]

By J. A. DeFrance, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

The purpose of this paper is to report recent findings regarding concentrations, amounts of solution and methods of application in the chemical control of crabgrass, the most serious weed enemy of lawns, putting greens and other turf.

Tests were conducted on plots of the Rhode Island Agricultural Experiment Station and the athletic field of Rhode Island State College. The turf was composed of Kentucky bluegrass, Chewing's fescue and Colonial bent. It was maintained at a height of approximately 1 inch and is considered fairly representative of lawns, fairways, or other turf areas in New England. The turf was uniformly infested with crabgrass, of which two species, *Digitaria ischaemum* and *D. sanguinalis*, abound in the Northeast.

Observations made during 1946 at the Rhode Island Agricultural Experiment Station and reported by DeFrance (1) indicated that certain water-soluble mercurial formulations appeared to be effective crabgrass controls. Reporting tests conducted during 1947 on several hundred plots of lawn and putting-green turf with various mercurial formulations, sodium arsenite and 2,4–D preparations, DeFrance (2) stated that PMAS, PMAS-AA and Puratized 641 at 1:4,000 or 1:5,000 (1 part of the active ingredient to 5,000 parts of water with actual toxicant calculated on the basis of 10 gallons of solution to 1,000 square feet) used three times, at weekly intervals, gave excellent control of crabgrass on lawns composed of Kentucky bluegrass, Chewing's fescue and Colonial bent. Complete control of weeds, including common and fall dandelion, narrow and broad plantain, chickweed and crabgrass was obtained by three treatments at weekly intervals in August with a mixture of PMAS 1:6,000 and 2,4–D butyl ester 1:4,000, applied at the rate of 10 gallons to 1,000 square feet. The best time for treatment, with a minimum number of applications, was in July and August after seeds had germinated or were in the process of germination. Phenyl mercury formulations, such as PMAS and Puratized 641, also gave good control of some turf diseases, especially dollar spot. As a preventive against crabgrass and certain diseases in putting-green turf it appeared advisable to apply the chemicals at 1:8,000 or even 1:10,000 approximately once a month from June through September. Reporting work conducted during 1948, Engle and Wolf (3) indicated that certain phenyl mercury compounds were quite similar in their ability to control crabgrass and gave better control than sodium arsenite. Experimental chemicals FS33, S1840, S1861, S1980, S1998, and potassium cyanate merit further study be-

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cause of their ability to control crabgrass with few treatments, their non-poisonous nature, and lower cost. Two formulations, L–2687 and L–2988 of the Standard Oil Company of Indiana, were reported by Grigsby (4) as selective control agents for crabgrass.

## Materials and Methods

Chemicals used in the tests and their commercial sources were as follows:

Aero Cyanate, American Cyanamid Company, New York

PMAS-AA, and PMAS, compounds, W. A. Cleary Corporation, New Brunswick, New Jersey

TAT C-Lect (PMAS-AA), O. E. Linck Company, Clifton, New Jersey

2,4–D butyl ester, Sherwin-Williams Company, Cleveland, Ohio

Puraturf Crabgrass Killer, Puratized 641, Gallowhur Chemical Corporation, New York

Formulations L–2687 and L–2988, Standard Oil Company of Indiana, Chicago

100 Esso C G formulations, Standard Oil Development Company, Esso Laboratories, Linden, New Jersey

Rates of application ranging from 1 to 25 gallons per 1,000 square feet were used. Methods of application included the use of the following equipment:

Watering cans, 2½-gallon capacity, with regular round sprinklers which eject a coarse spray, and with Flaring Rose Sprinklers which eject a fan-like spray especially adapted for sprinkling flowers and flats in the greenhouse

A Brown's No. 4 open-head galvanized air-pressure type sprayer with disc orifice enlarged to $^1/_{16}$-inch for the 10-gallon rate, and with regular disc of $^1/_{32}$-inch orifice for the 5-gallon rate. Each disc orifice allowed for uniform coverage by going over the area twice in two directions.

The Rollosprayer which has two flat fan spray nozzles providing uniform coverage of 1,000 square feet with only 1 gallon of solution when application is made in 5-foot strips by going over the area twice in two directions. This is a 7-gallon-capacity machine that sprays as it is pushed along, designed and produced by Walter S. Lapp, Lansdale, Pennsylvania.

A $CO_2$-pressure type sprayer with constant-pressure valve, special 9-gallon tank, mounted on a 2-wheeled pushcart, furnished by O. E. Linck Company, Clifton, New Jersey

## Results and Discussion

*Area 1:*—A test to determine the effectiveness of various rates and methods of application was conducted on crabgrass-infested turf consisting of Kentucky bluegrass, fescue and Colonial bent.

Phenyl mercury acetate solutions, phenyl mercury acetate plus 2,4–D and certain commercial preparations were applied as follows: First treatment July 28, a clear day, soil fairly moist, temperature 84 de-

gress F; second treatment August 4, soil dry; third treatment, August 11, clear, soil dry, temperature 83 degrees F. Turf injury notes were recorded 1 week after the second treatment and 1 week after the third. Rates of application ranged from 2½ gallons to 25 gallons per 1,000 square feet. Crabgrass started rather late during the season; not until the last of July, when the weed had passed the 3-leaf stage, was the first treatment applied. The second was given a week later and the third a week after the second. Results of this test are presented in Table I.

In this study the phenyl mercury acetate concentrations that appear most practical are: 75.7 cc of 10 per cent PMAS-AA to 10 gallons of water which is 1: 5,000 at the 10-gallon rate per 1,000 square feet, or 7.57 cc per gallon when used in the garden sprayer. Equally good results were obtained with the 5-gallon rate when the same amount of toxicant was used, thus making the concentration 1: 2,500.

Dandelions and plaintain, as well as crabgrass, were completely controlled by a treatment with a mixture of PMAS-AA at 1: 6,000 and 2,4–D at 1: 4,000 (6.3 cc of 10 per cent PMAS-AA and 2.36 cc of a 40 per cent 2,4–D butyl ester for each gallon of water per 100 square feet) followed by two treatments at weekly intervals with PMAS-AA alone at 1: 5,000 or 1: 6,000 to eliminate any crabgrass that developed after the first or second treatment. This mixture applied at the 5-gallon rate per 1,000 square feet also gave perfect control of all weeds in the plots.

Preliminary tests with the watering can equipped with the coarse-spray nozzle indicated that 10 gallons was not sufficient for complete coverage. Therefore, the 20- and 25-gallon rates were used in this test. Although very little discoloration of the turf was noted, control was unsatisfactory. Even when the fine-spray nozzle was used on the watering can, complete coverage was not obtained at the 10-gallon rate; the 20-gallon rate appeared to give coverage, but not satisfactory control.

The 10- and 5- gallon rate of application with the garden-sprayer provided adequate coverage. The 2½-gallon rate gave uneven coverage, with many skips, and resulted in spotty control. Rates in excess of 10 gallons did not appear necessary and, in general, have not been so effective as the 10-gallon rate. The material runs off the leaves into the soil and more toxicant is needed.

The watering-can method cannot be recommended, as poor control was obtained when such large amounts of water were required to give coverage and avoid skips. It seems preferable to use a garden-sprayer such as the Brown's No. 4 that will apply the 5- or 10-gallon rate uniformly. Most home-owners, with an average-sized yard or garden, need such a sprayer for many other purposes.

In this test, as in 1947, some treatments were made early in the season when crabgrass was quite immature. One treatment gave complete kill of all crabgrass plants, but due to the prolonged period of germination, more crabgrass seed developed. Thus, a second, and frequently a third, treatment was necessary for complete, continuous control.

It was also noted again that better crabgrass control with less turf

TABLE I—METHODS AND RATES OF APPLICATION FOR CRABGRASS CONTROL AREA 1

| Plot | Material | Method and Rate Per 1,000 Sq. Ft. | Toxicant in Water | | Amount (Cc Per 1,000 Sq Ft) | | Maximum Turf Discoloration | | Per Cent Control | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 Treat-ment | 2, 3 Treat ments | 1 Treat-ment | 2, 3 Treat-ments | After 2 Treat-ments | After 3 Treat-ments | After 2 Treat-ments | After 3 Treat-ments |
| 1 | PMAS—AA (10 per cent) | Garden Sprayer—10-gal. | 1:4,000 | Same | 94.6 | Same | M* | M + | 95 | 100 |
| 2 | PMAS—AA (10 per cent) | Garden Sprayer—10-gal | 1:5,000 | Same | 75.7 | Same | M– | M | 93 | 100 |
| 3 | PMAS—AA (10 per cent) | Garden Sprayer—10-gal | 1:6,000 | Same | 63.1 | Same | L | L + | 90 | 100 |
| 4 | PMAS—AA (10 per cent) | Garden Sprayer—5-gal | 1:2,000 | Same | 94.6 | Same | M | M + | 96 | 100 |
| 5 | PMAS—AA (10 per cent) | Garden Sprayer—2½-gal | 1:1,000 | Same | 94.6 | Same | M spotty | S– | 89 | 97 |
| 6 | PMAS—AA (10 per cent) | Wat' Can, Fine Noz—10-gal | 1:4,000 | Same | 94.6 | Same | M + str'ky | M + | 60 | 80 |
| 7 | PMAS—AA (10 per cent) | Wat' Can, Fine Noz—20-gal. | 1:8,000 | Same | 94.6 | Same | VL | L | 50 | 85 |
| 8 | PMAS—AA (10 per cent) | Wat' Can, Coarse Noz.—20-gal | 1:8,000 | Same | 94.6 | Same | O | VL | 30 | 50 |
| 9 | PMAS—AA (10 per cent) | Wat' Can, Coarse Noz.—25-gal | 1:10,000 | Same | 94.6 | Same | O | VL | 30 | 50 |
| 10 | PMAS + 2,4-D (40 per cent) | Garden Sprayer—10-gal | 1:6,000<br>1:4,000 | Same | 63.1<br>23.6 | Same | M | M + | 89 | 100‡ |
| 11 | PMAS + 2,4-D (40 per cent) | Garden Sprayer—10-gal | 1:6,000<br>1:8,000 | Same | 63.1<br>11.8 | Same | M | M + | 89 | 100‡ |
| 12 | PMAS + 2,4-D (40 per cent) | Garden Sprayer—5-gal | 1:3,000<br>1:2,000 | Same | 63.1<br>23.6 | Same | M | M + | 90 | 100‡ |
| 13 | PMAS + 2,4-D (40 per cent) | Garden Sprayer—2½-gal | 1:1,500<br>1:1,000 | Same | 63.1<br>23 6 | Same | M + spotty | S | 85 | 95 |
| 14 | PMAS + 2,4-D (40 per cent) | Garden Sprayer—10-gal | 1:6,000<br>1:4,000 | 1·6,000 | 63.1<br>23.6 | 63.1 | M– | M | 90 | 100‡ |
| 15 | PMAS + 2,4-D (40 Per cent) | Garden Sprayer—10-gal. | 1:6,000<br>1:4,000 | 1:5,000 | 63.1<br>23.6 | 75.7 | M– | M | 92 | 100‡ |
| 16 | C—Lect (1.75 per cent)** | Garden Sprayer—13 3-gal | 1:7,700 | 1:7,700<br>1:5,010 | 372<br>558 | 558 to 50,470 | L | L + | 80 | 93 |
| 17 | C—Lect (1.75 per cent) | Garden Sprayer—10-gal | 1:4,000 | Same | 540 | | M | M + | 95 | 100 |
| 18 | C—Lect (1.75 per cent) | Garden Sprayer—10-gal | 1:5,000 | Same | 432 | | M– | M | 95 | 100 |
| 19 | C—Lect + WCL**, † | Garden Sprayer—13.3-gal | 1:7,700<br>1:4,900 | Same | 372<br>124 | 372 to 50,470 | M | M + | 85 | 96 |
| 20 | C—Lect + WCL (8.2 per cent 2,4-D) | Garden Sprayer—10-gal | 1:6,000<br>1:4,000 | Same | 360<br>115 | | M | M + | 89 | 100‡ |
| 21 | C—Lect + WCL 8.2** | Garden Sprayer—13.3-gal | 1:7,700<br>1:4,900 | 1:7,700 | 372<br>124 | 372 to 50,470 | M– | M | 85 | 95 |

*Turf discoloration recorded as O, L, M and S = None, light, medium and severe.
**Rate recommended by manufacturer.
†Weed C-Lect.
‡Indicates control of all weeds present including crabgrass, dandelion and plantain.

TABLE II—TEST OF VARIOUS METHODS OF APPLICATION WITH THE SAME AMOUNT OF TOXICANT DIFFERENT AMOUNTS OF WATER FOR CRABGRASS CONTROL, AREA 2

| Plot | Material | Toxicant in Water | Method | Amount (Cc Per 1,000 Sq Ft | Turf Discoloration | | | Per Cent Control | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 Treatment | 2 Treatments | 3 Treatments | 1 Treatment | 2 Treatments | 3 Treatments |
| 1 | PMAS—AA (10 per cent) | 1:4,000 | Garden Sprayer | 94.6 in 10 gal | L | L + | M | 58 | 94 | 100 |
| 2 | PMAS—AA (10 per cent) | 1:400 | Rollosprayer | 94.6 in 1 gal | L | L + | M | 62 | 96 | 100 |
| 3 | PMAS—AA (10 per cent) | 1:800 | $CO_2$ Pressure | 94.6 in 2 gal | L | L + | M | 61 | 95 | 100 |

injury or discoloration is obtained if the soil is moist and the temperature not excessive at time of application. Other factors, such as the amount and size of crabgrass being equal, it appears easier to kill crabgrass in good turf on fertile soil than in poor starved turf. Most lawns are under fed and thus unable to compete against crabgrass and other weeds. In any program of weed prevention and control, the established principles of good agronomic practices and turf culture should be followed.

*Area 2:*—In order to test applications using the same amount of toxicant in different quantities of water, a series of plots 1,000 feet square was set up on the athletic field. The plots were infested with approximately 25 per cent crabgrass in the 3-leaf stage and beyond. Applications were made July 30, August 10 and 19. Table II shows methods, rates used, and results with respect to turf discoloration and crabgrass control.

The type of sprayer employed, that is, garden sprayer, Rollosprayer or the $CO_2$ pressure type, made no apparent difference in discoloration of the turf caused by the toxicant, when uniformily applied, or in the ultimate control which resulted. The amount of solution, whether 1, 2, or 10 gallons per 1,000 square feet, likewise made no apparent difference. Uniform coverage, without harmful overlapping or skipping, was provided by the three different sprayers with the varying amounts of water and 100 per cent continuous control was obtained.

*Area 3:*—To test certain new chemicals for crabgrass control, a series of plots was set up on the athletic field, designated as Area 3. The turf was composed of a mixture of Colonial bent, Kentucky bluegrass and Chewing's fescue and was uniformly infested with crabgrass. The first treatment was applied September 1 when the soil was dry. Crabgrass was fairly mature and forming seed heads. A second treatment was applied September 15.

Good control was given by the following non-mercurial chemicals, some of which appear to have a promising future. They are considered economical and non-toxic to humans:

A 0.5 to 1.0 per cent solution of Aero Cyanate (potassium cyanate) applied at 5 and 10 gallons per 1,000 square feet

Esso products CG 16, 17 and 18 at 800 to 1,000 cc in 1 gallon per 100 square feet

PMAS 118 and 119 at concentrations of 1: 1,000 and 1: 2,000 on the basis of 10 gallons of solution to 1,000 square feet

*Area 4:*—One hundred herbicidal formulations designated by code numbers were supplied by the Esso Laboratories of the Standard Oil Development Company for screening as selective crabgrass killers during 1948. These materials were applied at three different rates to crabgrass infested turf plots composed of bent grass, bluegrass and fescue.

The first treatments were applied July 15 when crabgrass was in the 2- and 3-leaf stages. According to the apparent ability of the materials to control crabgrass without severe permanent injury to basic turf grasses, 47 of the 100 materials were selected for further study at various rates of application.

The first treatments in the second test were applied August 25, when crabgrass was nearing maturity. Soon after the second treatments, on September 1 and 15, many of the chemicals caused defoliation of the crabgrass plants. Possibly some of the chemicals killed the newly formed seed but did not defoliate the plants. It was difficult to ascertain the effect on the seed as distinguished from foliage or plant injury. This cannot be noted until the coming season, when further observations will be made on the treated plots. On the basis of the tests, 23 of the materials are suggested for further study. Seven of these appeared to give good control, and 16 fair control. They are designated as Esso CG 2, 3, 4, 5, 6, 7, 11, 14, 16, 17, 18, 23, 24, 33, 35, 36, 39, 43, 51, 55, 78, 86, and 93.

*Areas 1 and 5:*—In a preliminary test, L–2687 and L–2988, petroleum base compounds, were applied to plots at rates suggested by Dr. Grigsby. These rates were inadequate for complete coverage with the garden type sprayer when the compounds were used alone and not mixed with water. Therefore, two other tests were conducted on Areas 1 and 5, at suggested and increased rates, using an emulsifying agent and water.

The L–2687 and L–2988 compounds provided fair control without any definite permanent turf injury. They appeared to stunt the crabgrass plants by defoliation or a general shrinking, accompanied by lack of seed-head formation and consequent maturity. These plots will be observed the coming season, when more definite conclusions on control can be drawn.

*Area 6:*—Puraturf Crabgrass Killer and Puratized 641 were applied where turf was infested with crabgrass. Treatments were made August 8, 19 and September 1 at 1 : 4,000 at the 10-gallon rate per 1,000 square feet. Turf discoloration and estimated control are presented for the various treatments as follows:

| | Turf Discoloration | | | Estimated Per Cent Control | | |
|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 1st | 2nd | 3rd |
| Puraturf Crabgrass Killer | light | light + | medium | 35 | 61 | 83 |
| Puratized 641. . . . | light + | medium | medium + | 51 | 90 | 95 |

## Summary and Conclusions

Tests in 1948 on crabgrass control confirmed the 1947 observations by indicating that PMAS-AA (10 per cent), a water solution of a phenyl mercury organic complex, gave excellent control at 1 : 5,000, actual toxicant in 10 gallons of water per 1,000 square feet. There was no permanent injury to basic turf grasses such as Kentucky bluegrass, Chewing's fescue and Colonial bent. Comparable results were obtained when the same amount of toxicant was applied in less water, that is, 5, 2 or 1 gallon per 1,000 square feet.

TAT-C-Lect, the commercial preparation containing PMAS-AA, produced like results when applied at the same rate of active material as PMAS-AA (10 per cent). Puraturf Crabgrass Killer and Puratized 641 performed fairly well.

The use of a watering can with regular nozzle should be avoided. Control was much poorer than that obtained with the ordinary type 3- or 4-gallon garden sprayer when the active material was used at the same rate. The poor control provided by the use of the watering can was undoubtedly due to the large amount of water necessary (at least 20 gallons per 1,000 square feet) for proper coverage.

On small areas a garden-type sprayer is suggested. For larger areas, any type sprayer that will give uniform coverage may be used. The volume of water may vary from 1 to 10 gallons, according to the sprayer, but the amount of active material applied to each 1,000 square feet must be constant.

For maximum control with minimum number of applications, treatment should be made when the soil is moist, the temperature not excessive, and after the crabgrass seed has germinated, such as, late in July and August. The healthier the turf, the better the control will be, with less injury to the desirable grasses.

Turf infested with weeds such as dandelion and plaintain, in addition to crabgrass was freed of all such weeds by one application of a mixture of PMAS-AA 1:6,000 and 2,4–D 1:4,000, active material in 10 gallons of water per 1,000 square feet, followed by two sprayings at weekly intervals with PMAS-AA alone at 1:6,000. The combination of PMAS-AA and 2,4–D can also be used successfully with reduced amounts of water, provided the active material is the same per unit area.

The fact that a small volume of water is equally effective as a larger one increases the usefulness of the materials tested for crabgrass control. To provide for uniform coverage and distribution of the chemical, be sure the amount of water is sufficient to cover the area.

When PMAS-AA (10 per cent) is used at 1:5,000 on the basis of 10 gallons per 1,000 square feet, the following calculations are applicable:

3,785 cc 1 gal) ÷ 5,000 = .757 cc of 100 per cent PMAS-AA which is 7.57 cc of the 10 per cent material to be used for 100 square feet

473 cc (1 pint) ÷ 7.57 = 6,248 square feet to be covered with 1 pint, or 2.5 ounces to 1,000 square feet

In a power sprayer for large areas:

Use 1 pint 10 per cent for 6,000 to 6,400 square feet in 10, 20 or 50 gallons of water, depending on the type of sprayer

Use 7 pints of 10 per cent to 1 acre in 50, 100 or 200 gallons of water

In a 3- or 4-gallon pressure-type garden sprayer for small areas, when a 2.5 per cent material is employed:

Use 2 ounces of 2.5 per cent PMAS-AA in 1 gallon for 200 square feet

Use 6 ounces of 2.5 per cent PMAS-AA in 3 gallons for 600 square feet

Use 10 ounces of 2.5 per cent PMAS-AA in 5 gallons for 1,000 square feet

Use 1 pint of 2.5 per cent PMAS-AA in 8 gallons for 1,600 square feet

In a watering can for very small areas:

Use 1 ounce of 2.5 per cent PMAS in 2 gallons for 100 square feet

Some equipment, like the Rollosprayer, will cover 1,000 square feet with 1 gallon of solution; therefore, use 10 ounces of 2.5 per cent material in 1 gallon of water. In the $CO_2$ pressure sprayer, which covers 1,000 square feet with 2 gallons of solution, use 10 ounces of 2.5 per cent material in 2 gallons of water.

Two new non-mercurial PMAS compounds, 118 and 119, gave good control and are considered economical and non-toxic to humans.

Seven new formulations designated as Esso CG 2, 4, 14, 16, 17, 18 and 24 gave good control. Some of these materials defoliate and possibly kill the crabgrass plants without objectionably discoloring the turf. The L-2687 and L-2688 compounds provided fair control without any definite permanent turf injury. A 1 per cent solution of Aero Cyanate gave fairly good control but discoloration of the turf was quite noticeable. In most cases, however, there was no permanent turf injury.

## Literature Cited

1. DeFrance, J. A. Water-soluble mercurials for crabgrass control in turf. *The Greenkeeper's Reporter.* 15 (1). January 1947.
2. ———— Crabgrass control in turf. *Proc. Northeastern Weed Control Conf.* 99–112. February 1948.
3. Engle, Ralph E., and Wolf, Dale E. Chemicals for crabgrass control. *Proc. Northeastern Weed Control Conf.* 159–163. January 1949.
4. Grigsby, B. H. Selective control of crabgrass. *Mich. Agr. Exp. Sta. Quart. Bul.* May 1948.

# The Effect of Certain Mediums and Watering Methods on the Rooting of Cuttings of Some Deciduous and Evergreen Plants[1]

By L. C. Chadwick, *Ohio State University, Columbus, Ohio*

During the past three years several experiments in plant propagation have been conducted in the Department of Horticulture at the Ohio State University. While some of these experiments are of a minor nature individually, together they are of sufficient value to report.

These experiments have dealt with the effect of rooting mediums and watering methods on the rooting of softwood cuttings of deciduous plants, and hardwood cuttings of narrow and broadleaf evergreens.

## Materials and Methods

All cuttings were handled in a south lean-to type propagating house equipped with a Binks humidity system. This system of humidification, as well as the watering methods used, consisting of manual subirrigation, automatic constant level subirrigation and overhead, are the same as outlined by Houston and Chadwick (1).

All cuttings were made and stuck in the usual way. Treatments with growth substances were as indicated with each experiment. Shading and bottom heat was provided as required.

## Softwood Cuttings of Some Deciduous Shrubs

Cuttings were taken, treated and handled as indicated in Table I. Humidity was maintained in the propagating house at approximately 70 per cent. Temperature and light intensity varied considerably during the summer months. Both difficult and easy rooting subjects were under test.

The data in Table I indicate that a mixture of one-half No. 7 silica sand and one-half No. 1 vermiculite, gave the best rooting results. This was particularly noticeable in the manual subirrigated plots. When a comparison is made on the basis of the rooting occurring in the mixture of sand and vermiculite, overhead watering gave the best results, with little difference between constant level and manual subirrigation.

With cuttings of *Kolkwitzia amabilis,* low light intensity and high rooting-medium moisture often resulted in excessive callus production and poor quality roots. Cuttings of *Malus baccata mandshurica* root with difficulty. The highest percentage of rooting obtained occurred on cuttings taken July 18, 1947, amounting to 57 per cent. These were rooted in the sand and vermiculite mixture under manual subirrigation. One of the difficulties involved in rooting cuttings of *M. baccata* and its variety mandshurica is the serious foliage drop. High light intensity and relatively low moisture in the rooting medium seem conducive to

[1]Acknowledgement is given Albert D. Quinn, Donald Hillenmeyer, Hiram J. Johnson and Richard Miller for their aid in conducting these experiments.

TABLE I—THE EFFECT OF VARIOUS WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING PERCENTAGES OF SOFTWOOD CUTTINGS OF SOME DECIDUOUS PLANTS

| Time in Bench | No. Cuttings Per Plot | Manual Subirrigation (Per Cent) | | | Constant Level Subirrigation (Per Cent) | | | Watered Overhead (Per Cent) | Treatment and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Silica Sand, No. 7 | Vermiculite, No. 1 | Half Silica Sand, No. 7 and Half Vermiculite No. 1 | Silica Sand, No. 7 | Vermiculite, No. 1 | Half Silica Sand, No. 7 and Half Vermiculite No. 1 | Half Silica Sand, No. 7 and Half Vermiculite No. 1 | |
| | | | | | *Hamamelis vernalis* | | | | |
| Jul 3 to Aug 20, 1947 | 50 | 14 | 26 | 36 | 14 | 44 | 12 | 58 | Hormodin No. 2; best in high humidity but medium moisture in rooting medium. |
| | | | | | *Kolkwitzia amabilis* | | | | |
| Jun 24 to Aug 5, 1947 | 50 | 86 | 84 | 90 | 82 | 90 | 84 | 94 | Hormodin No. 1; give high light intensity; poorer roots in constant level. |
| | | | | | *Lonicera korolkowi* | | | | |
| June 24 to Aug 5, 1947 | 50 | 58 | 52 | 84 | 58 | 68 | 94 | 68 | Hormodin No. 1; give high light intensity. |
| | | | | | *Malus baccata mandshurica* | | | | |
| Jul 8 to Aug 21, 1947 | 25 | 24 | 12 | 8 | 8 | 16 | 8 | 24 | Hormodin No. 2· make basal cut ¼ inch below mode. |
| | | | | | *Myrica caroliniensis* | | | | |
| Jul 18 to Aug 22, 1947 | 25 | 100 | 52 | 80 | 60 | 92 | 72 | — | Hormodin No. 2; use loose medium; female plants slower to root than male. |
| | | | | | *Viburnum pubescens canbyi* | | | | |
| Jun 24 to Aug 4, 1947 | 50 | 52 | 36 | 64 | 58 | 66 | 70 | 64 | Hormodin No. 3; give high light intensity. |
| | | | | | *Weigela, Bristol Ruby* | | | | |
| Jul 1 to Aug 19, 1947 | 50 | 96 | 74 | 96 | 94 | 86 | 98 | 98 | Hormodin No. 1; give medium moisture in rooting medium. |

better maintenance of foliage. The relatively low rooting percentage obtained with cuttings of *Viburnum pubescens canbyi* can be explained by the fact that one row of a double row of cuttings was shaded by adjacent cuttings. The unshaded row rooted nearly 90 per cent.

During the spring of 1948 cuttings of several varieties of hybrid lilacs were taken and rooted in various rooting mediums and under different methods of watering in a south and in a north lean-to propagating house. Unfortunately, an infestation of Phytophora blight in the south lean-to prevented the recording of any comprehensive results. Indications were, however, that a mixture of one-half bank sand and one-half No. 2 vermiculite, was superior to either the bank sand or the vermiculite alone. Manual subirrigation gave slightly superior results when compared with the other watering methods.

Some of the data recorded on the lilac cuttings placed in the north lean-to house are given in Table II. Twenty-five cuttings were used per plot and all cuttings were treated with Hormodin No. 1. Cuttings were taken April 29th and May 4th.

Data in Table II indicate a fact already well known in commercial practice, that varieties of hybrid lilacs vary greatly in their ability to root. One-half No. 7 silica sand, and one-half No. 2 vermiculite proved superior to the silica sand alone as a rooting medium. With easy rooting varieties such as Charles Joly and George Bellair, manual subirrigation gave better results than overhead watering. This was not true with the more difficult to root varieties. An infestation of Phytophora blight was at least partially responsible for the low rooting percentages.

TABLE II—THE EFFECT OF WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING OF SOFTWOOD CUTTINGS OF HYBRID LILACS

| Variety | Watered Overhead | | Manual Subirrigation | |
|---|---|---|---|---|
| | Silica Sand, No. 7 (Per Cent) | Half Silica Sand, No. 7 and Half Vermiculite, No. 2 (Per Cent) | Silica Sand, No. 7 (Per Cent) | Half Silica Sand, No. 7 and Half Vermiculite, No. 2 (Per Cent) |
| Charles Joly | 48 | 68 | 60 | 72 |
| George Bellair | 0 | 28 | 40 | 84 |
| Jan Van Tol | 0 | 0 | 4 | 0 |
| June | 16 | 28 | 44 | 24 |
| Lucie Baltet | 24 | 20 | 16 | 20 |
| Ludwig Spaeth | 48 | 52 | 32 | 32 |
| Mme. Antoine Buchner | 36 | 40 | 20 | 24 |
| Paul Thirion | 0 | 40 | 28 | 4 |
| Pres. Fallieres | 0 | 0 | 0 | 0 |
| Pres. Grevy | 12 | 8 | 20 | 8 |
| Pres. Poincare | 8 | 0 | 28 | 16 |
| Reaumur | 0 | 12 | — | — |

Softwood cuttings of Deutzia lemoine taken July 13, 1948 rooted 100 per cent in silica sand, watered overhead in 20 days. Rooting was somewhat poorer in a mixture of equal parts of No. 7 silica sand and No. 2 vermiculite, watered overhead and in silica sand watered by manual subirrigation. Results were much poorer where manual subirrigation was used with No. 2 vermiculite and with the mixture. Similar results were obtained with softwood cuttings of *Philadelphus virginalis* taken July 13, 1948.

## Cuttings of Some Evergreen Plants

*Broadleaf Evergreens:*—Both softwood and hardwood cuttings of several broadleaf evergreens were used in experimental tests. The softwood cuttings were handled the same as outlined for the softwood cuttings of deciduous shrubs. Some of the data compiled are presented in Table III.

The data in Table III indicate that softwood cuttings of the broadleaf evergreens used root readily in all three of the rooting mediums. All methods of watering were satisfactory.

Hardwood cuttings of several broadleaf evergreens were taken during the winter of 1947–48 and handled in a south lean-to propagating house. Tests concerned the use of various mediums and watering methods. Data are presented in Tables IV and V.

As is evident from the data presented in Tables IV and V, no one rooting medium or watering method proved the best for all of the types of plants used. Variations occur even within species and varieties.

*Cotoneaster dammeri* can be rooted successfully from cutting taken in October. Vermiculite No. 1, or a mixture of equal parts of vermiculite No. 1 and No. 7 silica sand proved to be satisfactory rooting mediums. Constant level and manually operated subirrigation watering were more effective than watering overhead, provided the moisture content or level was not maintained too high. Higher rooting percentage would have resulted if the records had been taken 6 to 7 weeks after sticking rather than after the 5 week interval.

*Pachistima canbyi* can be rooted successfully from cuttings taken in October. Good rooting will occur in about 10 to 12 weeks. Overhead watering proved superior to constant level or manual subirrigation. A mixture of equal parts of No.7 silica sand and No.1 vermiculite proved to be a very satisfactory rooting medium. A mixture of equal parts of No. 7 silica sand and sphagnum peat and equal parts of No. 7 silica sand, No. 1 vermiculite and sphagnum peat gave very good results with the overhead watering method. Silica sand No. 7, was not a good rooting medium for *Pachistima canbyi* cuttings.

Tests with *Pieris japonica* were conducted to determine the effect of time of taking the cuttings, of the rooting medium and of the method of watering on rooting. The time of taking did not influence materially the total percentage of cuttings rooted. However, cuttings taken in January rooted in less time and the quality of the roots were much better than on those taken in November and December. Data on rooting percentage of the November cuttings were taken after 9, 12 and 16 weeks. The percentage of rooting was nearly as high after 9 weeks as after 16 weeks, when the final data was recorded.

*Pieris japonica* cuttings did not respond satisfactorily to constant level subirrigation. Considering all the mediums used there was little difference between overhead watering and manual subirrigation. The best rooting medium varied with the time of taking the cuttings and the watering method. With overhead watering a mixture of equal parts of No. 7 silica sand and No. 1 vermiculite gave good results for all periods the cuttings were taken. Results were slightly superior in No.

TABLE III—THE EFFECT OF VARIOUS WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING PERCENTAGE OF SOFTWOOD CUTTINGS OF SOME BROADLEAF EVERGREEN PLANTS

| Time in Bench | No. Cuttings Per Plot | Manual Subirrigation (Per Cent) | | | Constant Level Subirrigation (Per Cent) | | | Watered Overhead (Per Cent) | Treatment and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Silica Sand, No. 7 | Vermiculite, No. 1 | Half Silica Sand, No. 7 and Half Vermiculite No. 1 | Silica Sand, No. 7 | Vermiculite, No. 1 | Half Silica Sand, No. 7 and Half Vermiculite No. 1 | Half Silica Sand No. 7 and Half Vermiculite No. 1 | |
| *Euonymus fortunei* | | | | | | | | | |
| Jul 18 to Aug 21, 1947 | 25 | — | 100 | — | 92 | 96 | — | — | Hormodin No. 2; roots good in all treatments. |
| *Euonymus fortunei carrierei* | | | | | | | | | |
| Jul 18 to Aug 21, 1947 | 25 | 96 | 92 | 92 | 92 | 100 | 88 | 100 | Hormodin No. 2; little difference between treatments. |
| *Euonymus fortunei vegetus* | | | | | | | | | |
| Jul 18 to Aug 21, 1947 | 25 | — | 100 | — | 92 | 96 | — | — | Hormodin No. 2; good roots in all treatments. |
| *Euonymus kiautschovicus* | | | | | | | | | |
| Jul 18 to Aug 21, 1947 | 25 | 100 | 96 | 100 | 100 | 100 | 96 | 100 | Hormodin No. 2; excellent rooting in all plots; high water level in constant subirrigation plots detrimental. |
| *Pyracantha coccinea pauciflora* | | | | | | | | | |
| Jul 15 to Aug 20, 1947 | 25 | 92 | 88 | 96 | 96 | 100 | 100 | 88 | Hormodin No. 2; good roots in all treatments. |

TABLE IV—THE EFFECT OF VARIOUS WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING PERCENTAGE OF HARDWOOD CUTTINGS OF SOME BROADLEAF EVERGREEN PLANTS

| Time in Bench | No. Cuttings Per Plot | Manual Subirrigation (Per Cent) | | | Constant Level Subirrigation (Per Cent) | | | Watered Overhead (Per Cent) | | | | | Treatment and Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Silica Sand No. 7 | Vermiculite No. 1 | Equal Parts of Silica Sand No. 7 and Vermiculite No. 1 | Silica Sand No. 7 | Vermiculite No. 1 | Equal Parts of Silica Sand No. 7 and Vermiculite No. 1 | Silica Sand No. 7 | Vermiculite No. 1 | Equal Parts of Silica Sand No. 7 and Verm. No. 1 | Equal Parts of Silica Sand No. 7 and Sphagnum Peat | Equal Parts of Silica Sand No. 7, Vermiculite, No. 1 and Sphagnum Peat | |
| *Cotoneaster dammeri* | | | | | | | | | | | | | |
| Oct 27 to Dec 3, 1947 | 15 | 40 | 73 | 80 | 53 | 86 | 53 | — | — | 60 | — | — | Hormodin No. 3; best results in vermiculite or mixture of sand and vermiculite. |
| *Pachistima canbyi* | | | | | | | | | | | | | |
| Oct 9, 1947 to Jan 26, 1948 | 25 | 72 | 92 | 84 | 60 | 64 | 84 | 72 | 64 | 100 | 96 | 96 | Hormodin No. 3; best results in sand and vermiculite watered overhead. |
| *Pieris japonica* | | | | | | | | | | | | | |
| Nov 4, 1947 to Mar 1, 1948 | 25 | 60 | 44 | 40 | 40 | 24 | 4 | 28 | 44 | 64 | 56 | 36 | Hormodin No. 2. Sand and vermiculite watered overhead gave highest quality roots. |
| Dec 4, 1947 to Mar 18, 1948 | 25 | 60 | 40 | 24 | 8 | 24 | 4 | — | — | 56 | 64 | 20 | Sand and peat gave highest quality roots. |
| Jan 8 to Mar 18, 1948 | 25 | 72 | 12 | 36 | 32 | 24 | 12 | 68 | 32 | 64 | 16 | 24 | Overhead watering preferable. |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Rhododendron catawbiense Var. Chas. Bagley* | | | | | | | |
| Sep 6, 1947 to Feb 6, 1948 | 10 | 0 | 0 | 20 | 0 | 30 | 0 | 10 | 40 | 20 | 10 | — | Hormodin No. 3; best rooting in vermiculite watered overhead; stem cuttings. |
| | | | | | | *Rhododendron catawbiense Var. Roseum Elegans* | | | | | | | |
| Sep 6, 1947 to Jan 13, 1948 | 16 | 56(1) | 37 | 50 | 6 | 12 | 12 | 37(2) | 62 | 37(3) | 25 | — | Hormodin No. 3. (1, 2, 3)-per cent rooted Mar 18, 1948 was 68, 43 and 50 respectively; stem cuttings. |
| Oct 10, 1947 to Feb 6, 1948 | 25 | 64 | 24 | 44 | 48 | 24 | 12 | 12 | 36 | 28 | 76 | 40 | Leaf bud cuttings. |
| Dec 8, 1947 to Mar 18, 1948 | 25 | 40 | 12 | 32 | 20 | 40 | 28 | — | 12 | 36 | 76 | 32 | Leaf bud cuttings. |
| | | | | | | *Viburnum rhytidophyllum* | | | | | | | |
| Oct 3, 1947 to Jan 5, 1948 | 25 | 96 | 92 | 96 | 80 | 88 | 96 | 72 | 76 | 96 | 100 | 48 | Hormodin No. 2. Stem cuttings. |
| Oct 3, 1947 to Jan 5, 1948 | 25 | 40 | 44 | 56 | 64 | 44 | 60 | 24 | 72 | 60 | 64 | 56 | Leaf-bud cuttings. |
| Nov 10, 1947 to Feb 9, 1948 | 20 | 65 | 85 | 90 | 65 | 80 | 70 | 15 | — | 50 | 75 | 70 | Stem cuttings. |
| Nov 10, 1947 to Feb 9, 1948 | 20 | 40 | 80 | 90 | 60 | 50 | 65 | 70 | 70 | 85 | 75 | 70 | Lear-bud cuttings. |

TABLE V—THE EFFECT OF VARIOUS WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING PERCENTAGE OF CUTTINGS OF *Ilex opaca*

| Time in Bench | No. Cuttings Per Plot | Manual Subirrigation (Per Cent) | | | Constant Level Subirrigation (Per Cent) | | | Watered Overhead (Per Cent) | Treatment and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Silica Sand, No. 7 | Vermiculite, No. 1 | Equal parts of Silica Sand, No. 7 and Vermiculite No. 1 | Silica Sand, No. 7 | Vermiculite, No. 1 | Equal parts of Silica Sand, No. 7 and Vermiculite No. 1 | Equal parts of Silica Sand No. 7 and Vermiculite No. 1 | |
| Aug 18, 1947 to Jan 25, 1948 (160 days) | 25 | 72 | 40 | 92 | 60 | 56 | 56 | 60 | Rootone. |
| Sep 18, 1947 to Feb 25, 1948 (160 days) | 25 | 76 | 76 | 76 | 40 | 72 | 80 | 72 | Foliage must be retained for satisfactory rooting. |

7 silica sand, however, for cutting taken in January. Where manual subirrigation was used, No. 7 silica sand gave by far the best results. Differences are due to the percentage of moisture in the rooting medium.

Tests on rhododendron cuttings were run to determine the effect of rooting media, watering methods and kind of cutting, in correlation with the time of taking on the rooting percentage. It has been shown previously (2, 3), that late August is the best time to take cuttings of rhododendrons. One of the purposes of these tests was to determine whether by varying the rooting medium and the watering method, the cuttings could be taken and rooted satisfactorily during late fall and winter.

Stem cuttings of Charles Bagley rhododendron did not give satisfactory rooting when taken in early October. Overhead watering and a No. 1 vermiculite rooting medium were superior to other methods and mediums tried.

Leaf-bud cuttings of *Roseum Elegans* rhododendron proved somewhat superior to stem cuttings. With the leaf-bud cuttings there was little increase in rooting after 12 weeks. There was essentially no difference in the rooting ability of cuttings taken in October and December. High quality roots were produced in somewhat shorter time on cuttings taken in December than on those taken in October. Best rooting occurred in the overhead watered plots with manual subirrigation being superior to constant level watering. A mixture of equal parts of No. 7 silica sand and sphagnum peat proved to be the best rooting medium. This was not only true with the percentage rooted but in the quality of the roots produced.

Stem cuttings were superior to leaf-bud cuttings with *Viburnum rhytidophyllum*. The best time of taking varied with the kind of cutting used. With stem cuttings, October cuttings were superior to those taken in November. The reverse was true with the leaf-bud cuttings. Good rooting percentage had occurred after 7 weeks in some plots with the October taken cuttings. All plots of October cuttings showed good results. Somewhat better quality roots were produced in the mixtures of sand and peat and in sand and vermiculite. Manual subirrigation and overhead watering were superior to constant level subirrigation.

Cuttings of *Ilex opaca* were taken August 18, September 3, September 18, October 1 and November 1. Cuttings taken September 3 were injured in shipment and cuttings taken October 1 and November 1 did not root satisfactorily. For these reasons, results of these tests are not included in Table V. The data in Table V indicate that cuttings of *Ilex opaca* can be expected to give good rooting when taken from mid August to mid September. A mixture of equal parts of No. 7 silica sand and No. 1 vermiculite proved superior to the other rooting mediums used. Manual subirrigation and constant level subirrigation were better than overhead watering.

*Narrowleaf Evergreens:*—Fifty cuttings of each plant per plot were used in this experiment in a south lean-to propagating house. The watering methods used were overhead and manual and constant level

subirrigation. The rooting mediums used were No. 7 silica sand, No. 5 silica sand, No. 2 vermiculite, No. 1 vermiculite, and fine bank sand. Humidity was maintained at 70 per cent.

The results of this experiment are shown in Table VI. The data presented indicate that vermiculite produced the most favorable rooting results. Vermiculite produces roots that are flexible, longer, thinner, and straighter than the roots that were produced in the other mediums. Silica sand No. 7 and silica sand No. 5 also produce large, long, flexible roots. Cuttings rooted in fine bank sand had short, brittle roots undesirable for potting due to excessive breaking. Vermiculite is very light and appears to have excellent oxygen-moisture relationship to which may be attributed these satisfactory root qualities. The data also show that the overhead watering method produced the most favorable rooting results. Manual subirrigation was somewhat better than constant level subirrigation.

TABLE VI—THE EFFECT OF VARIOUS WATERING METHODS AND ROOTING MEDIUMS ON THE ROOTING PERCENTAGE OF EVERGREEN PLANTS (SOUTH LEAN-TO; FIFTY CUTTINGS PER PLOT; TREATED WITH HORMODIN NO. 3)

| Time in Bench | Manual Subirrigation (Per Cent) | | | Constant Level Subirrigation (Per Cent) | | | Watered Overhead (Per Cent) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 7 Silica Sand | No. 1 Vermiculite | Bank Sand | No. 7 Silica Sand | No. 1 Vermiculite | Bank Sand | No. 7 Silica Sand | No. 1 Vermiculite | Bank Sand | No. 2 Vermiculite | No. 5 Silica Sand |
| *Taxus media browni* | | | | | | | | | | | |
| Dec 12, 1946 to Mar 13, 1947 | 30 | 78 | 6 | 68 | 76 | 16 | 100 | 100 | 82 | 84 | 94 |
| *Taxus cuspidata* | | | | | | | | | | | |
| Dec 30, 1946 to Mar 24, 1947 | 94 | 94 | 40 | 94 | 92 | 28 | 98 | 98 | 96 | 94 | 100 |
| *Juniperus chinensis pfitzeriana* | | | | | | | | | | | |
| Dec 21, 1946 to Mar 27, 1947 | 54 | 32 | 30 | 22 | 32 | 42 | 40 | 74 | 74 | 66 | 8 |
| *Juniperus virginiana kosteri* | | | | | | | | | | | |
| Dec 22, 1946 to Mar 20, 1947 | 20 | 16 | 10 | 2 | 14 | 4 | 20 | 16 | 24 | 20 | 0 |
| *Thuja occidentalis elegantissima* | | | | | | | | | | | |
| Dec 29, 1946 to Mar 26, 1947 | 90 | 84 | 72 | 74 | 76 | 64 | 94 | 92 | 92 | 94 | 82 |

## SUMMARY AND CONCLUSIONS

1. Experiments reported herewith deal with the effects of rooting mediums and watering methods on the rooting of softwood and hardwood cuttings of some deciduous plants and narrowleaf and broadleaf evergreens.

2. Cuttings were handled in a south lean-to type propagating house equipped with a Binks humidification system.

3. For softwood cuttings of the deciduous plants used, a mixture of equal parts of No. 7 silica sand and No. 1 vermiculite proved to be a better rooting medium than either one of these materials used alone. Overhead watering was superior to manual or constant level subirrigation. Some exceptions are noted.

4. Cuttings of hybrid lilacs rooted better in a mixture of equal parts of No. 7 silica sand and No. 2 vermiculite than in silica sand alone. Results with watering methods were not conclusive.

5. Softwood cuttings of *Euonymus fortunei* and its varieties carrieri and vegetus, *Euonymus kiautschovicus* and *Pyracantha coccinia pauciflora* rooted readily in all mediums and with all of the watering methods used. All of these subjects are easily rooted.

6. Cuttings of *Cotoneaster dammeri* root readily when taken in October. Vermiculite No. 1 or equal parts No. 1 vermiculite and No. 7 silica sand are satisfactory rooting mediums. Providing the moisture content is carefully adjusted, constant level and manual subirrigation are satisfactory watering methods.

7. *Pachistima canbyi* can be rooted readily from cuttings taken in October in 10 to 12 weeks. Overhead watering gave better results than the other methods used. Mixtures of equal parts of (a) No. 7 silica sand and No. 1 vermiculite, (b) No. 7 silica sand and sphagnum peat and (c) No. 7 silica sand, No. 1 vermiculite and sphagnum peat are good rooting mediums.

8. Cuttings of *Pieris japonica* root better when taken in January than they do when taken in November and December. Overhead watering or manual subirrigation were satisfactory when No. 7 silica sand or a mixture of equal parts of No. 7 silica sand and No. 1 vermiculite are used as rooting mediums.

9. Leaf-bud cuttings are superior to stem cuttings for *Roseum elegans* rhododendron. Cuttings taken in December rooted as readily as those taken in October. Better quality roots were produced on cuttings taken in December. Best rooting occurred in a medium composed of equal parts of No. 7 silica sand and sphagnum peat and when watered overhead.

10. Stem cuttings are superior to leaf-bud cuttings for *Viburnum rhytidophyllum*. October cuttings were particularly satisfactory when rooted in mediums of equal parts of No. 7 silica sand and sphagnum peat or No. 7 silica sand and No. 1 vermiculite. Manual subirrigation and overhead watering were satisfactory.

11. Cuttings of *Ilex opaca* rooted well from cuttings taken in August and September. Best results were obtained when cuttings were rooted in a mixture of equal parts of No. 7 silica sand and No. 1 vermiculite and when watered by manual subirrigation.

12. Vermiculite No. 1 produced more satisfactory rooting with cuttings of narrowleaf evergreens than bank sand, No. 2 vermiculite, No. 7 silica sand or No. 5 silica sand. Vermiculite No. 2 and No. 7 silica sand were satisfactory rooting mediums. Vermiculite No. 1 and silica sand produced more roots and of a more desirable quality than the other rooting mediums used. Overhead watering, in general, was superior to either manual or constant level subirrigation with cuttings of narrowleaf evergreens. The level of water maintained in the constant level subirrigation method depends on the time of year, type of plant propagated and kind of medium used. The moisture level must be adjusted carefully for satisfactory results.

### Literature Cited

1. Houston, Rayford, and Chadwick, L. C. Some results of the effect of controlled humidity, mediums, and watering methods on the rooting of cuttings of some deciduous and evergreen plants. *Proc. Amer. Soc. Hort. Sci.* 49: 410–416. 1947.
2. Skinner, Henry T. A new propagation method for hybrid Rhododendrons. *Jour. N. Y. Bot. Garden* 40: 83–89. 1939.
3. ———— Further observations on the propagation of Rhododendron and Azaleas by stem and leaf cuttings. *Proc. Amer. Soc. Hort. Sci.* 37: 1013–1018. 1940.

# Some Results with the Use of Opaque Structures for Propagation by Cuttings

By L. C. Chadwick, *Ohio State University, Columbus, Ohio*

During the past few years considerable interest has developed concerning the possibility of using opaque structures, in which atmospheric conditions might be closely controlled, for propagation purposes.

Stoutemyer and Close (2) report good rooting in opaque structures in which light was furnished by cold cathode and fluorescent lamps. In most cases they found continuous illumination most satisfactory. In a few cases 16 hour daily illumination was preferable. Lamps at a height of 18 and 24 inches furnished 300 and 150 foot candles of light to the cuttings. Using many light colors, they found that the red-orange end of the light spectrum was more important in the rooting of cuttings than the blue end. None of the colors, however, had any advantage over the 3500 degrees white.

Stoutemyer, Close and O'Rourke (3) working on the propagation of citrus, Hibiscus and Bouganvillae, among other plants, report obtaining exceptionally good rooting under fluorescent light, which surpassed the rooting obtained in a regular propagating house.

## Materials and Methods

During the past two years several experiments have been conducted at Ohio State University using an opaque structure equipped with fluorescent lights. Experiments have included the propagation of deciduous and evergreen plants by softwood and hardwood cuttings. In most cases corresponding controls have been run in a lean-to type greenhouse equipped with a Binks humidification system.

The opaque structure used in these experiments was an insulated underground basement with raised benches over which were suspended industrial type fluorescent lamps of the F40 + 12 type and reflectors with built-in transformers. Each unit held two 40-watt tubes 36 inches long except as noted otherwise in connection with the individual experiments. Lights were used at various heights above the cuttings and for different periods of time. Temperature and humidity readings will be reported for each experiment. A small blower was mounted in the door to draw the air out of the basement and the intake of fresh air was through eight 1-inch holes bored in the lower part of the door. Humidity was controlled by the use of Binks nozzles and syringing. The propagation benches used were raised, shallow V-bottom, watertight, galvanized iron tanks, 6 inches deep at the point of the V, 8 feet long and 2 feet wide. All tanks were equipped so that watering could be accomplished by manual or constant level subirrigation as described by Houston and Chadwick (1). The rooting mediums used are men-

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tioned with each experiment. Unless otherwise mentioned cuttings were made and handled according to the usual accepted commercial method.

## EXPERIMENTAL RESULTS

*Experiments With Greenhouse Roses:*—Cuttings of Better Times and Golden Rapture roses were used in these experiments. In the basement house the fluorescent light were suspended 6 inches above the cuttings and run continuously. Temperature ranged from about 62 to 65 degrees F during the winter months and about 7 degrees F warmer during the summer. Humidity was maintained from 60 to 70 per cent. Silica sand No. 7 was used as a rooting medium, and 25 cuttings were used per plot.

The response of cuttings of Better Times and Golden Rapture roses to different light sources is given in Table I.

TABLE I—THE EFFECT OF VARIOUS LIGHT COLORS ON THE ROOTING PERCENTAGE OF BETTER TIMES AND GOLDEN RAPTURE ROSE CUTTINGS

| Time in Bench | Gold Light (Per Cent) | Red Light (Per Cent) | Daylight Light (Per Cent) | White Light (Per Cent) |
|---|---|---|---|---|
| | | *Better Times* | | |
| Dec 11, 1946 to Jan 14, 1947 | 62 | 32 | 82 | 67 |
| Jan 17, 1947 to Feb 11, 1947 | 64 | — | 82 | 76 |
| | | *Golden Rapture* | | |
| Oct 18, 1946 to Nov 26, 1946 | 70 | 28 | 63 | 66 |
| Dec 11, 1946 to Jan 14, 1947 | 61 | 22 | 76 | 72 |

As the data in Table I indicate, red light gave a less favorable rooting response while the best results were obtained with the daylight lights. These results are in agreement with the findings of Stoutemyer and Close (2). In this experiment the light intensities as measured with a Weston light meter placed directly under the lights and on top of the cuttings were as follows: Gold — 100 foot candles, red — 20 foot candles, daylight — 130 foot candles and white — 110 foot candles. Light intensities varied as much as 70 to 80 foot candles from the center to the sides of the bench. The difference in light intensity is responsible for variations in rooting response. The rooting response under daylight, white and gold lights compared favorable with that obtained under ordinary greenhouse conditions. Rooting was slightly more rapid under artificial light and it was also noticed that much more top growth was produced during the rooting period under light than under greenhouse conditions.

To study further the effects of light intensity on the rooting of cuttings of Better Times roses an experiment was set up to supply high and low light intensities. The relatively high light intensity, 240 to 280 foot candles was obtained by using six daylight lamps each 48 inches long and 1.5 inches in diameter. Three reflectors with two lamps in each, were suspended 22 inches above the surface of the medium. The relatively low light intensity, 90 to 120 foot candles was obtained by using two daylight lamps in separate reflectors located as described

above. It was noted that the air temperatures under the high light intensity was 3 to 4 degrees F higher than under the low light intensity. The results given in Table II are the averages of three sets of cuttings taken in October, December and January. Twenty-five cuttings were used per plot in each test. Vermiculite No. 1 was used as the rooting medium and temperature and humidity was maintained as in the previous experiment.

TABLE II—ROOTING RESPONSE OF BETTER TIMES ROSE CUTTINGS TO HIGH AND LOW LIGHT INTENSITIES

| Plant and Time in Bench | Low Light Intensity | | High Light Intensity | |
|---|---|---|---|---|
| | One-Leaf Cuttings | Two-Leaf Cuttings | One-Leaf Cuttings | Two-Leaf Cuttings |
| Better Times Rose—30 Days. | 73 | 73 | 87 | 95 |

The data in Table II indicate that better rooting response was obtained under the high light intensity. This better rooting response was manifest not only by a higher rooting percentage but by a better quality root system. This response was especially noticeable with the two-leaf cuttings.

*Experiments with Softwood Cuttings of Shrubs:*—During the summers of 1946, 1947 and 1948, softwood cuttings of several deciduous shrubs were handled in the basement house under white fluorescent lights. Lights were suspended 12 inches above the cuttings, operated continuously, and gave light intensities varying from 150 to 170 foot candles directly under the lights. Light intensity dropped to as low as 50 to 75 foot candles at the corners of the benches. Several rooting mediums were used but the figures in Table III are for the medium giving the best results. Temperature ranged from 67 to 70 degrees F and humidity from 60 to 70 per cent. In most cases comparable sets of cuttings were handled in a lean-to greenhouse.

It will be noticed from the data presented in Table III that in not a single case where comparable figures are available did cuttings respond as favorable under white fluorescent light as under normal greenhouse conditions. Light intensity in the greenhouse in the middle of the day varied from 900 to 2200 foot candles. It is probable that the unfavorable rooting under fluorescent lights is due to the low light intensity prevailing under these experiments.

*Experiments With Softwood Cuttings of Broadleaf Evergreens:*—The same set of conditions existed for these experiments as outlined for the softwood cuttings of deciduous shrubs. Results are presented in Table IV. Data presented in Table IV show that easily rooting broadleaf evergreens respond favorably to artificial illumination but in no case was the rooting percentage or quality of the roots better under fluorescent lights than under ordinary greenhouse conditions.

*Experiments With Hardwood Cuttings of Narrowleaf Evergreens:*—A single reflector each contianing two 40-watt tubes was suspended approximately 12 inches above the cuttings. Continuous illumination was provided. The temperature in the basement averaged 62 to 65

TABLE III—THE ROOTING RESPONSE OF CUTTINGS OF SEVERAL DECIDUOUS SHRUBS UNDER ARTIFICIAL AND NORMAL ILLUMINATION

| Time in Bench | No. Cuttings Per Plot | White Fluorescent Light | | Greenhouse Conditions | |
|---|---|---|---|---|---|
| | | Medium | Per Cent Rooted | Medium | Per Cent Rooted |
| | | *Actinidia arguta* | | | |
| Jul 2, 1946 to Aug 16, 1946 | 75 | No. 7 Silica sand | 40 | No. 2 Vermiculite | 82 |
| | | *Fontanesia fortunei* | | | |
| Jul 2, 1946 to Aug 10, 1946 | 25 | No. 2 Vermiculite | 0 | No 2 Vermiculite | 88 |
| | | *Ginkgo biloba* | | | |
| Jul 21, 1948 to Aug 26, 1948 | 25 | No. 7 Silica sand | 68 | ——— | — |
| | | *Hamamelis vernalis* | | | |
| Jul 3, 1947 to Aug 20, 1947 | 50 | Half No. 7 Silica sand and half No. 1 Vermiuclite | 18 | Half No. 7 Silica sand and half No. 1 Vermiculite | 58 |
| | | *Kolkwitzia amabilis* | | | |
| Jun 25, 1947 to Aug 5, 1947 | 50 | Half No. 7 Silica sand and half No 1 Vermiculite | 36 | Half No. 7 Silica sand and half No. 1 Vermiculite | 94 |
| | | *Lonicera korolkowi* | | | |
| Jun 25, 1947 to Aug 5, 1947 | 50 | Half No 7 Silica sand and half No 1 Vermiculite | 64 | Half No. 7 Silica sand and half No 1 Vermiculite | 94 |
| | | *Myrica caroliniensis* | | | |
| Jul 18, 1947 to Aug 22, 1947 | 25 | Half No. 7 Silica sand and half No. 1 Vermiculite | 0 | Half No. 7 Silica sand and half No. 1 Vermiculite | 80 |
| | | *Styrax japonica* | | | |
| Jul 2, 1946 to Aug 10, 1946 | 25 | No. 7 Silica sand | 28 | No. 7 Silica sand | 80 |
| | | *Viburnum burkwoodi* | | | |
| Jul 2, 1946 to Aug 10, 1946 | 100 | No. 2 Vermiculite | 18 | No. 2 Vermiculite | 97 |
| | | *Viburnum opulus* | | | |
| Jul 17, 1948 to Aug 17, 1948 | 25 | No 7 Silica sand | 72 | ——— | — |
| | | *Viburnum pubescens canbyi* | | | |
| Jul 2, 1946 to Aug 10, 1946 | 88 | No. 7 Silica sand. | 86 | No. 2 Vermiculite. | 94 |
| Jun 24, 1947 to Aug 4, 1947 | 50 | Half No. 7 Silica sand and half No. 1 Vermiculite | 50 | Half No. 7 Silica sand and half No. 1 Vermiculite | 70 |
| | | *Viburnum tomentosa* | | | |
| Jul 21, 1948 to Aug 17, 1948 | 25 | No. 7 Silica sand | 56 | ——— | — |
| | | *Weigela, Bristol Ruby* | | | |
| Jul 1, 1947 to Aug 19, 1947 | 50 | Half No 7 Silica sand and half No. 1 Vermiculite | 90 | Half No. 7 Silica sand and half No. 1 Vermiculite | 98 |

degrees F and the temperature of the rooting medium was maintained at 70 to 72 degrees F with the use of electric cables. Humidity was maintained at approximately 60 to 70 per cent. A duplicate set of cuttings were handled in a south lean-to propagating house. Silica sand No. 7 and No. 1 vermiculite were used as rooting mediums but the

TABLE IV—THE ROOTING RESPONSE OF CUTTINGS OF SEVERAL BROADLEAF EVERGREENS UNDER ARTIFICIAL AND NORMAL ILLUMINATION

| Time in Bench | No. Cuttings Per Plot | White Flourescent Light | | Greenhouse Conditions | |
|---|---|---|---|---|---|
| | | Medium | Per Cent Rooted | Medium | Per Cent Rooted |
| | | *Euonymus fortunei carrierei* | | | |
| Jul 18, 1947 to Aug 21, 1947 | 25 | Half No. 7 Silica sand and half No. 1 Vermiculite | 96 | Half No. 7 Silica sand and half No. 1 Vermiculite | 100 |
| | | *Euonymus fortunei vegetus* | | | |
| Jul 18, 1947 to Aug 21, 1947 | 25 | Half No. 7 Silica sand and half No. 1 Vermiculite | 100 | No. 1 Vermiculite | 100 |
| | | *Euonymus kiautschovicus* | | | |
| Jul 18, 1947 to Aug 21, 1947 | 25 | Half No 7 Silica sand and half No. 1 Vermiculite | 92 | Half No. 7 Silica sand and half No. 1 Vermiculite | 100 |
| | | *Pyracantha coccinea pauciflora* | | | |
| Jul 15, 1947 to Aug 20, 1947 | 25 | Half No 7 Silica sand and half No. 1 Vermiculite | 68 | Half No. 7 Silica sand and half No. 1 Vermiculite | 100 |
| Jul 17, 1947 to Aug 20, 1947 | 25 | | 76 | | 96 |

result of only the medium giving the best response is included in Table V. Fifty cuttings were used per plot.

The data in Table V indicate that better rooting response of cuttings of narrowleaf evergreens can be expected under greenhouse conditions than in an opaque structure equipped with fluorescent lights such as used in this experiment. Red light proved inferior to the other lights used. Gold lights proved better than white or daylight with three out

TABLE V—THE ROOTING RESPONSE OF CUTTINGS OF SEVERAL NARROWLEAF EVERGREENS UNDER ARTIFICIAL AND NORMAL ILLUMINATION

| Time in Bench | Percentage Rooting Under | | | | |
|---|---|---|---|---|---|
| | Red Light | Gold Light | White Light | Daylight Light | Greenhouse Conditions |
| | | *Juniperus chinensis pfitzeriana* | | | |
| Dec 21, 1946 to Mar 30, 1947 | 46 | 64 | 44 | 52 | 74 |
| | | *Taxus cuspidata* | | | |
| Dec 30, 1946 to Mar 24, 1947 | 22 | 74 | 78 | 68 | 98 |
| | | *Taxus media browni* | | | |
| Dec 12, 1946 to Mar 12, 1947 | 8 | 70 | 22 | 28 | 100 |
| | | *Thuja occidentalis elegantissima* | | | |
| Dec 29, 1946 to Mar 16, 1947 | 48 | 72 | 58 | 60 | 94 |

of the four plants used. Faulty electric heating cables under the medium in the daylight and white light plots may have been accountable in part for the lower rooting percentage in these plots. Cuttings under artificial illumination required somewhat less time to root than similar cuttings handled under greenhouse conditions.

## Summary and Conclusions

1. Experiments reported herewith were conducted to determine the possibility of using opaque structures equipped with fluorescent lights, and in which atmospheric conditions could be well controlled, for the propagation of plants by cuttings.

2. Experiments were conducted in an insulated underground basement with raised benches over which the fluorescent lights were suspended. For the most part duplicate lots of cuttings were handled in a lean-to type greenhouse.

3. With Better Times and Golden Rapture roses, using gold, red, daylight and white lamps, the most favorable rooting response was obtained with the daylight lamps. Red light gave the poorest rooting response. Rooting response varied in direct proportion to the foot candles of light supplied by the different lamps. Best results were obtained with the highest foot candles. The rooting response under daylight, white and gold lights compared favorably with that received under ordinary greenhouse conditions.

4. In experiments which included softwood cuttings of 13 deciduous shrubs, in not a single case was rooting as favorable under white fluorescent lights in an insulated basement as in a lean-to type greenhouse. The poor rooting response under the fluorescent lights is explained on the bases of low light and variable light intensity.

5. Rooting response of easily rooted broadleaf evergreens was favorable under fluorescent lights but in no case was the percentage of rooting higher or the quality of roots better than under greenhouse conditions.

6. While favorable rooting of cuttings of several narrowleaf evergreens was obtained under fluorescent lights, results were not better than those obtained under greenhouse conditions. Gold light gave the highest rooting response and red light the poorest.

7. Under conditions of these experiments, rooting response of cuttings handled in an opaque structure equipped with fluorescent lights, was not as favorable as similar lots of cuttings handled in a lean-to type greenhouse. The main obstacles encountered with such structures appear to be the supplying of sufficient light intensity and an even intensity to all parts of the rooting bench.

### Literature Cited


1. Houston, Rayford and Chadwick, L. C. Some results of the effect of controlled humidity, mediums, and watering methods on the rooting of cuttings of some deciduous and evergreen plants. *Proc. Amer. Soc. Hort. Sci.* 49: 410–416. 1947.
2. Stoutemyer, V. T., and Close, A. W. Rooting cuttings and germinating seeds under fluorescent and cold cathode lighting. *Proc. Amer. Soc. Hort. Sci.* 48: 309–325. 1946.
3. ———— and O'Rourke, F. L. Rooting greenwood cuttings without sunlight under fluorescent lamps. *Science* 101: 546. 1945.

# Register of New Fruit and Nut Varieties
# List No. 4

Compiled by Reid M. Brooks and H. P. Olmo,
*University of California, Davis, Calif.*

Cooperating Horticulturists

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Source for Previous Lists

List No. 1: *Proc. Amer. Soc. Hort. Sci.* 45: 467–490. 1944.
List No. 2: *Ibid.* 47: 544–569. 1946.
List No. 3: *Ibid.* 50: 426–442. 1947.

## REVISIONS, LIST NO. 2

### Cherry

*Late Lambert.*— See **Stark Royal Purple.**

**Stark Royal Purple** *(Late Lambert).*— Patent no. 627 renamed in 1948 by Stark Brothers Nurseries, Louisiana, Missouri, assignee and introducer.

## REVISIONS, LIST NO. 3

### Apple

**Saint Clair.**—Introduced commercially in 1947. Most nearly resembles Wealthy in fruit quality and in tree; more vigorous under climatic conditions of the Tennessee and Central Mississippi Valleys.

## LIST NO. 4

### Apple

**Beacon** *(Minnesota No. 423).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1936. Open pollinated seedling of Malinda; seed planted in 1908. Fruit: skin solid red; quality good; matures early. Tree: productive.

**Chestnut** *(Minnesota No. 240).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in November, 1946. Open pollinated seedling of Malinda; selected in 1921. Fruit: crab; large; pleasant nut-like flavor. Tree: vigorous; productive.

**Flame** *(Minnesota No. 635).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1943. Parentage unknown; selected in 1920. Fruit: crab; brightly colored; hangs well on tree. An ornamental variety.

**Folwell** *(Minnesota No. 237)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in June, 1922. Open pollinated seedling of a Malinda seedling grown by T. E. Perkins of Red Wing, Minnesota; selected in 1913. Fruit: large; attractive; quality good. Tree: most nearly resembles Hibernal.

**Haralson** *(Minnesota No. 90)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1923. Open pollinated seedling of Malinda; selected in 1913. Fruit: good cooking quality; attractive red; stores well. Tree: hardy.

*Hoosier Seedling* — See **Jongrimes.**

**Jongrimes** *(Hoosier Seedling)*.— Originated in Bloomfield, Indiana, by Roland S. Rogers. Introduced commercially in the 1920's. Patent no. 794; March 23, 1948; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; resembles Jonathan only in having some red color; bears no resemblance to Grimes. Fruit: yellow ground color streaked with red; tart; high dessert cooking quality; keeps about as well as Duchess; ripens two weeks ahead of Jonathan at a very favorable season; hangs in dense clusters unless thinned. Tree: bears well.

**Jubilee.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (R. C. Palmer). Introduced commercially in 1939. McIntosh x Grimes Golden; cross made in 1926; original tree planted in 1928; first fruited in 1934; selected in 1936 (A. J. Mann). Fruit: size medium; flesh firm, crisp, cream-colored, juicy; quality good; matures three weeks later than McIntosh; stores well until February. Tree: vigorous; as hardy as McIntosh to date. Named in 1939 in honor of the British Columbia Fruit Growers' Association's Golden Jubilee Convention.

*Melred.*— See **Red Melba.**

**Minjon** *(Minnesota No. 700)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1942. Parentage unknown, but probably Wealthy x Jonathan; selected in 1923. Fruit: quality good; skin solid dark red; flesh stained red as in Wealthy; most nearly resembles Jonathan in size, shape, and color; for home and commercial use.

**Minnehaha** *(Minnesota No. 300)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in March, 1920. Open pollinated seedling of Malinda; selected in 1914. Fruit: dark red; very attractive; rich flavor; season early winter.

*Minnesota No. 90.*— See **Haralson.**
*Minnesota No. 207.*— See **Wedge.**
*Minnesota No. 237.*— See **Folwell.**
*Minnesota No. 240.*— See **Chestnut.**
*Minnesota No. 300.*— See **Minnehaha.**
*Minnesota No. 423.*— See **Beacon.**
*Minnesota No. 635.*— See **Flame.**
*Minnesota No. 638.*— See **Redwell.**
*Minnesota No. 700.*— See **Minjon.**
*Minnesota No. 1007.*— See **Prairie Spy.**

**Prairie Spy** *(Minnesota No. 1007)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1940. Parentage unknown; seed planted in 1914; selected in 1923. Fruit: high dessert and culinary quality; flesh crisp and juicy; matures in October; most nearly resembles Northern Spy. Tree: hardy; vigorous.

**Red McIntosh.**— Originated in Dansville, New York, by Isaac C. Rogers. Introduced commercially in 1932. Bud mutation of McIntosh. Fruit: color dark solid red; in all other respects similar to its parent.

**Red Melba** *(Melred)*.— Origination unknown, but first noticed from a lot of nursery trees from the Wellington and Davidson Nurseries, Fonthill, Ontario, Canada. Introduced commercially in the 1940's. Bud mutation of Melba; discovered previous to 1937. Fruit: resembles Melba but is more highly colored, flesh firmer, bruises less easily, and is a few days later in maturity. Apparently identical sports have appeared in several localities in Canada.

**Redwell** *(Minnesota No. 638)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in November, 1946. Open pollinated seedling of Scott's Winter; seed planted about 1911; selected in 1923. Fruit: color very attractive bright medium red, russet dots; flesh cream, mild; quality good for baking, dessert, and sauce; matures about mid-October and keeps well until January. Tree: annual bearer.

**Spartan.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (R. C. Palmer). Introduced commercially in 1936. McIntosh x Newtown; cross made in 1926; original tree planted in 1928; first fruited in 1932; selected in 1936 (A. J. Mann). Fruit: size above medium; highly colored with solid dark red blush; flesh firm, crisp, white, juicy; quality very good, fully equal to McIntosh; matures two to three weeks later than McIntosh which it most nearly resembles; stores well until February. Tree: of McIntosh type as hardy as McIntosh to date; picks easily; more resistant to pre-harvest drop than McIntosh.

**Wedge** *(Minnesota No. 207)*.— From seed originally planted by Wyman Elliot, Minneapolis, Minnesota, and later selected in 1912 by the University of Minnesota Fruit Breeding Farm. Introduced commercially in June, 1922. Probably an open pollinated seedling of Ben Davis. Fruit: large; attractive; for fall and early winter use.

**Western Giant.**— Originated in Paskenta, California, by Earl Davies. Introduced commercially in the fall, 1948. Patent pending; to be assigned to United Nurseries, Red Bluff, California. Parentage unknown; discovered in June, 1947. Fruit: skin thick with a deep blush flecked with red; flesh creamy white; 4½ to 5 inches in diameter; weight 12 to 14 ounces; ripens before Astrachan at the 4,000 foot level on the west side of the Sacramento Valley in Tehama County, around July 5 to 12; keeps well in cold storage; most nearly resembles Alexander.

**Wickson.**— Originated in Ettersburg, California, by Albert F. Etter. Introduced commercially in 1944. Patent no. 724; March 4, 1947; assigned to George C. Roeding, Jr., California Nursery Company, Niles, California. Yellow Newtown x "Spitzenberg crab". Fruit: crab; a small apple for eating fresh as well as for pickling, jam, jelly, and cider; brilliant red; juicy; oblong.

**Young-Bearing Jonathan.**— Originated in Vera, Missouri, by Lloyd C. Stark. Introduced commercially in 1932. Bud mutation of Jonathan; discovered in 1924. Resembles Jonathan in every respect, except that the trees come into bearing at an earlier age.

## Apricot

**Improved Cluster.**— Originated in De Leon, Texas, by Stanley Carruth. Introduced commercially in 1937. Open pollinated seedling of Cluster; discovered in 1931. Fruit: quality poor; resembles Cluster; of little value horticulturally. Tree: very productive.

**Leslie.**— Originated in Morden, Manitoba, by the Dominion Experimental Station; selected at the Dominion Experimental Station (A. J. Mann), Summerland, British Columbia. Introduced commercially in 1943. Cross made in 1936 at Morden; original tree planted in 1938 and selected in 1942 at Summerland; named in honor of W. R. Leslie, Superintendent of the Dominion Experimental Station, Morden. Fruit: color pale; quality fair; inclined to be somewhat soft in handling; most nearly resembles Tilton. Tree: has proved hardy to date. Not recommended for commercial planting.

**Reliable.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (A. J. Mann). Introduced commercially in 1945. Wenatchee Moorpark x Hewetson; cross made in 1937; selected in 1942. Fruit: orange with a blush; quality fair; texture dry and firm, maintaining its firmness on the tree for about ten days after attaining full color; ships well; a canning variety.

**Sun Glo.**— Originated in Entiat, Chelan County, Washington, by Otto H. Heider. Introduced commercially in May, 1946. Patent no. 751; August 12, 1947; assigned to Columbia and Okanogan Nursery Company, Wenatchee, Washington. Parentage unknown; discovered about 1942. Fruit: ripens uniformly and about seven days before Wenatchee Moorpark.

## Cherimoya

**McPherson.**— Originated in Orange, California, by Bill Weber. Introduced commercially in 1933. Parentage unknown; original tree still growing in the McPherson Brothers orchard, after whom the variety was named Fruit: quality good; moderate size; skin smooth but with some development of tubercles; mid-season to late in maturity. Tree: vigorous and quite productive even without hand pollination.

## Cherry

**Black Giant.**— Originated in Sebastopol, California, by Luther Burbank. Introduced by Stark Brothers Nurseries, Louisiana, Missouri; trademarked by this company. Parentage unknown. Fruit: sweet; skin black; flesh firm, blood red; pit small; large; ships well. Tree: fairly hardy.

**Honey Heart.**— Originated in Santa Rosa, California, by Luther Burbank. Introduced commercially in 1934. Patent no. 41; November 8, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown. Fruit: sweet; skin yellow with a red blush; flesh firm, cream color; most nearly resembles Napoleon.

**Meyer.**— Originated in Cedarburg, Wisconsin, by Mrs. Ottilie R. Meyer. Introduced commercially in 1948. Patent no. 764; October 7, 1947; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; discovered in 1925. Fruit: sweet; color deep red; larger size than most standard varieties including Schmidt, Bing, and Lambert; not quite as firm as Bing, but ships well; quality very high; most nearly resembles Schmidt. Tree: very hardy and productive.

**Sparkle.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (A. J. Mann). Introduced commercially in 1944. Open pollinated seedling of Empress Eugenie; cross made in 1936; selected in 1942. Fruit: flavor sweet, sprightly; flesh white, firm; size medium to small; appearance attractive; skin has a bright luster which suggested the varietal name; fairly resistant to cracking; rounder and less conical than Napoleon which it most nearly resembles; matures one week earlier than Napoleon. Tree: vigorous; upright grower; a pollinizer for Bing, Lambert, Napoleon and Van; pollinated by the above and Deacon. Not recommended for commercial planting, but is a good variety for the home garden.

**Van.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (A. J. Mann). Introduced commercially in 1944. Open pollinated seedling of Empress Eugenie; cross made in 1936; selected in 1942. Fruit: Bing type; sweet; black; bright luster to skin; somewhat resistant to cracking; as large as Bing and slightly firmer and quite as good in quality as Bing; slightly earlier in season than Bing. Tree: vigorous; upright grower; a pollinizer for Bing and Lambert; pollinated by Bing, Deacon, Lambert, and Napoleon. Variety named in honor of J. R. Van Haarlem, Horticultural Experiment Station, Vineland, Ontario.

## Cherry Plum

*Minnesota No. 144.*— See **Nicollet.**
*Minnesota No. 145.*— See **St. Anthony.**

**Nicollet** *(Minnesota No. 144)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1925. *(Prunus avium* x *P. pennsylvanica)* x *P. besseyi:* seed planted in 1912; selected in 1916 or 1917. Fruit: cherry plum; small, round; sour cherry flavor. Tree: dwarf, bushlike.

**St. Anthony** *(Minnesota No. 145)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. *Prunus besseyi* x *P. salicina* hort. var. Satsuma; selected in 1915. Fruit: cherry-plum type; rich flesh color; semi-freestone; for culinary use only. Tree: vigorous; early and prolific bearing habit.

**Zumbra.**—Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. *(Prunus avium* x *P. pennsylvanica)* x *P. besseyi;* selected in 1916. Fruit: flesh firm and crisp; quality good for cooking. Tree: vigorous; dwarf; bushy; hardy.

### Chestnut

**Mayseptjan.**— Originated in Nevada County, California, by the Felix Gillet Nursery (C. E. Parsons). Introduced commercially in 1932. Parentage unknown; from a seedling brought in from the Reihl orchard, Alton, Illinois; selected in 1930. Nut: large; quality good; matures in early fall. Tree: bears well.

### Currant

**Cascade** *(Minnesota No. 70).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1942. Open pollinated seedling of Diploma; selected in 1926. Fruit: larger than Red Lake, and matures one week later. Bush: productive; erect; medium vigor.

*Minnesota No. 70.*— See **Cascade.**

### Date

**Desert Dew.**— Originated in Yuma, Arizona, by C. D. McGinnis. Introduced commercially in 1946. Discovered in 1909 among some off-shoots taken from Bard Valley, California to the McGinnis date grove in Yuma. Fruit: ripens earlier, slightly larger, better flavor before processing than Deglet Noor which it most closely resembles; does not crack or check.

### Fig

**King.**— Originated in Madera, California, by Sisto Pedrini of the Western Evergreen Company, San Francisco, California. Introduced commercially in 1940 by the King Fig Plantation, San Francisco, California. Trademarked in 1941. Parentage unknown; discovered in June, 1930. Fruit: sweet; skin thin, smooth, dark green; flesh pink; matures in cool coastal climates as far north as British Columbia; most nearly resembles Genoa; one of the White San Pedro group; large; pyriform; of excellent quality.

### Gooseberry

**Como** *(Minnesota No. 43.)*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Pearl x Columbus; cross made in 1908. Fruit: greenish yellow; quality good. Bush: very productive; resistant to sunscald.

*Minnesota No. 43.*— See **Como.**

### Grape

**Athens.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Hubbard x Portland; cross made in 1925. Fruit: early; black; large clusters; most nearly resembles Concord. Vine: very productive.

**Bluebell** *(Minnesota No. 158).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1944. Parentage unknown; selected in 1923. Fruit: most nearly resembles Concord in size and color; high quality for dessert, juice or jelly; matures about mid-September. Vine: productive; vigorous; hardy.

**Blue Jay** *(Minnesota No. 69).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1944. Parentage unknown; selected in 1923. Fruit: dark blue; nearly size of Concord; good for juice and jelly; matures mid-September. Vine: hardy; productive; requires cross-pollination.

**Brocton.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1919. Brighton x Station Seedling No. 125 (Winchell x Diamond); cross made in 1899. Most nearly resembles Niagara. Fruit: white, quality good; flavor less foxy than Niagara.

**Bronx Seedless.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station in cooperation with the New York Botanical Garden (A. B. Stout). Introduced for trial in 1937. Station Seedling No. 8536

(Goff x Iona) x Sultanina; cross made in 1925. Fruit: large; red; seedless; quality good; large clusters; cracks easily during wet weather. Recommended where cracking is not prevalent.

**Buffalo.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Herbert x Watkins; cross made in 1921. Most nearly resembles Herbert. Fruit: black; pleasing flavor; ripens about one week before Concord; most nearly resembles Herbert. Vine: productive.

**Eden.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Ontario x Station Seedling No. 10085 (Triumph x Mills); cross made in 1923. Fruit: pleasing flavor; most nearly resembles Concord; clusters are too scraggly for a commercial variety.

**Hector.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1937. Chasselas Rose x Brocton; cross made in 1923. Fruit: attractive; red; long, slender clusters; quality good; subject to mildew; most nearly resembles Chasselas Rose.

**Kendaia.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1939. Portland x Hubbard; cross made in 1925. Fruit: matures early; pleasing flavor; most nearly resembles Moore Early. Vine: productive; hardy. Recommended as promising in New Hampshire.

*Minnesota No. 45.*— See **Red Amber.**
*Minnesota No. 66.*— See **Moonbeam.**
*Minnesota No. 69.*— See **Blue Jay.**
*Minnesota No. 158.*— See **Bluebell.**

**Moonbeam** *(Minnesota No. 66).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1944. Parentage unknown; selected in 1923. Fruit: large; greenish yellow; bland flavor; larger than Concord; ripens in early September. Vine: vigorous; easy to propagate; winter hardy.

**Red Amber** *(Minnesota No. 45).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1944. Parentage unknown; selected in 1923. Fruit: sweet; reddish amber; aromatic; berry smaller than Concord; cluster medium size, compact; very good quality; ripens in early September. Vine: hardy.

**Ruby.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1938. Keuka x Ontario; cross made in 1923. Fruit: attractive; red; quality good; ripens after Concord; most nearly resembles Chasselas Rose. Vine: productive.

**Sanderson Special.**—Originated in Glendale, Arizona, by Chester A. Sanderson. Introduced commercially in 1948. Patent no. 782; January 20, 1948; unassigned. Parentage unknown; discovered in 1942. Fruit: slipskin type; skin maroon-colored; similar to Concord but milder; table grape. Vine: vigorous.

**Urbana.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (S. A. Beach). Introduced for trial in 1912. Ross x Mills; cross made in 1899. Fruit: red; keeps well; flesh crisp; quality good; matures late; most nearly resembles Catawba. Vine: subject to mildew.

**Yates.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (Richard Wellington). Introduced for trial in 1937. Mills x Ontario; cross made in 1923. Fruit: red; skin tough; quality good; ships well; season before Catawba, which it most nearly resembles.

## NECTARINE

**Pioneer.**—Originated in Ontario, California, by Herbert C. Swim. To be introduced commercially in 1949. Patent no. 787; March 9, 1948; assigned to Armstrong Nurseries, Inc., Ontario, California. (Gold Mine nectarine x Rio Oso Gem peach) x self; selected August, 1943. Fruit: freestone; flesh yellow with red coloring, especially around pit; skin red, thin, sufficiently crisp to be eaten with

ease; flavor rich, distinctive; ripens in same season as Gold Mine (last week in July); most nearly resembles Lippiatt's Late Orange nectarine; suitable primarily for home planting or local markets. Tree: resistant to delayed foliation, being similar to Redwing peach; flowers large, pink, very showy, making it desirable for ornamental purposes.

**Stark Early Flame.**— Originated in Sheffield, Alabama, by R. H. King. Introduced commercially in 1946. Patent no. 759; September 2, 1947; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Open pollinated seedling of Flaming Gold; discovered in 1942. Fruit: flesh yellow; semi-freestone; skin attractive red and deep yellow; ripens 14 days before Flaming Gold, around August 1; quality high; most nearly resembles known parent.

## Peach

**Flamingo.**— Originated in Ontario, California, by Walter E. Lammerts. Introduced commercially in January, 1948. Patent no. 661; November 20, 1945; assigned to Armstrong Nurseries, Inc., Ontario, California. Open pollinated seedling of Rio Oso Gem; selected in 1940. Fruit: more uniform and more smoothly shaped than Rio Oso Gem which it most nearly resembles; ripens five to ten days earlier than Rio Oso Gem and in same season as J. H. Hale. Tree: lower chilling requirement than Rio Oso Gem, being similar to that of Socala, making this new variety better suited to southern California and other mild winter areas; begins to leaf and flower earlier than Rio Oso Gem.

*Improved Pallas.*— See **Melba.**

**Jubilant.**— Originated in Danville, Morgan County, Alabama, by Penn-Orr-McDaniel Orchards (William Arthur Penn, Lovic Orr, and Joseph C. McDaniel). Introduced commercially in 1947. Trademark and patent pending. Bud mutation of Golden Jubilee; discovered and first propagated in 1945. Fruit: flesh yellow; freestone; as firm as Golden Jubilee, which it most nearly resembles; shape slightly rounder, higher color, ripens seven to ten days earlier than Golden Jubilee. Tree: growth vigorous; productive. Useful as a similar variety to precede Golden Jubilee.

**Loring.**— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station (Paul H. Shepard). Introduced commercially in 1946. Frank x Halehaven; selected in 1943. Fruit: freestone; flesh yellow; large, firm; ripens 10 days before Elberta; most nearly resembles Golden Jubilee.

**Lyman Late.**— Originated in St. Helena, California, by W. W. Lyman. Introduced commercially about 1925. Parentage unknown; discovered in 1920. Fruit: flesh yellow; freestone; large; ripens 10 to 14 days later than Krummel at St. Helena.

**Melba** *(Improved Pallas).*— Originated in San Antonio, Texas, by a Mr. Yost. Introduced commercially in 1936. Parentage unknown; originated as a chance seedling in the yard of Mr. Yost; later propagated by local nurseries as Improved Pallas; Wolfe Nursery, Stephenville, Texas, obtained buds from F. P. Wittman, Horticulturist, Missouri Pacific Lines, Dilley, Texas, and renamed it Melba since Improved Pallas was misleading. Fruit: size of Belle of Georgia; pit small; honey flavor; ripens 25 days ahead of Elberta. Tree: adapted to mild winters.

**Merrill's Beauty.**— Originated in Red Bluff, California, by Grant Merrill. Introduced commercially in June, 1947. Open pollinated seedling of J. H. Hale; selected in June, 1943. Fruit: freestone; flesh yellow; very large; highly colored; ripens 5 weeks before Elberta and one week before Red Haven.

**Merrill's Delicious.**— Originated in Red Bluff, California, by Grant Merrill. Introduced commercially in June, 1947. Open pollinated seedling of J. H. Hale; selected in June, 1943. Fruit: freestone; flesh yellow; ripens 5 weeks before Elberta; flavor very good.

**Merrill's Gem.**— Originated in Red Bluff, California, by Grant Merrill. Introduced commercially in June, 1947. J. H. Hale x Red Bird; selected June, 1943. Fruit: clingstone; flesh yellow; texture firm to hard; skin dark red; large; matures 7 weeks before Elberta.

**Merrill's June.**— Originated in Red Bluff, California, by Grant Merrill. Introduced commercially in June, 1947. Open pollinated seedling of J. H. Hale; selected in June, 1943. Fruit: semi-freestone; flesh yellow; matures 6 weeks before Elberta.

**Royal Fay.**— Originated in Porterville, California, by Fred D. Williams. Introduced commercially in 1945. Patent no. 795; March 21, 1948; assigned to Fred D. Williams, Route 2, Box 470, Porterville, California. Bud mutation of Fay Elberta; discovered in 1941. Fruit: freestone; flesh yellow; firm; pubescence sparse and short; similar to parent but with higher color.

**Spotlight.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (J. E. Britton). Introduced commercially in 1946. Veteran x Rochester; cross made in 1934; original tree planted in April, 1937; selected in 1942 (A. J. Mann). Fruit: flesh yellow; firm, good to above fair in quality; semi-clingstone; attractive high color; excellent canning variety; matures 1 week earlier than Rochester.

**Superior.**— Originated in Summerland, British Columbia, by the Dominion Experimental Station (J. E. Britton). Introduced commercially in 1946. J. H. Hale x Veteran; cross made in 1933; original tree planted in 1936; selected in 1941 (A. J. Mann). Fruit: size above medium; flesh yellow; practically freestone (being similar to Vedette and Valiant); flesh moderately firm; quality above fair; fair as a canning variety; similar season to that of Valiant and Veteran.

## PEAR

**Bantam** *(Minnesota No. 3)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1940. Parentage unknown; seed planted in 1914 or 1915. Fruit: small; flesh tender, melting, juicy; early; quality good. Tree: very hardy; resistant to fire blight.

**Chapin.**— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (U. P. Hedrick). Introduced commercially in 1945. Open pollinated seedling of Seckel; from seed borne in 1908; first full crop in 1920. Fruit: about size of Seckel, little longer in shape; greenish yellow with considerable russet; richly aromatic; very sweet; season after Beurré Giffard and ahead of Early Seckel; desirable for home use; most nearly resembles Seckel.

**Christmas Holiday.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1940 by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown. Fruit: large; skin russet; appearance attractive; quality good; matures late; most nearly resembles Bosc in shape and flavor. Tree: produces well.

**Devoe.**— Originated in Marlboro, New York, by Charles A. Greiner. Introduced commercially in 1947. Patent no. 728; March 25, 1947. Parentage unknown, but thought to be an open pollinated seedling of Clapp Favorite. Fruit: shape similar to Bosc. Tree: said to be resistant to fire blight and pear psylla.

**Max-Red Bartlett.**— Originated in Zillah, Washington, by A. D. MacKelvie. Introduced commercially in August, 1945. Patent no. 741; July 1, 1947. Trademarked Max-Red. Bud mutation of Bartlett; discovered in 1938. Fruit: skin cranberry-red; ripens 12 to 15 days later than Bartlett.

*Minnesota No. 1.*— See **Parker.**

*Minnesota No. 3.*— See **Bantam.**

**Parker** *(Minnesota No. 1)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1934. Open pollinated seedling of a Manchurian cultivated pear (probably *Pyrus communis*); selected in 1920. Fruit: medium to large; quality good. Tree: fairly hardy.

## PLUM

**Anoka** *(Minnesota No. 118)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Burbank x De Soto; cross made in 1915; selected in 1918. Fruit: medium to large; red; firm; flesh yellow; quality only fair; clingstone. Variety has been abandoned because of low quality.

**Elephant Heart.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1929 by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1920. Fruit: flesh blood red; freestone; very large; quality good. Tree: strong; hardy.

**Elliot** *(Minnesota No. 8)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. *Prunus salicina* (probably Apple variety) x *P. americana* (unnamed seedling); selected in 1911. Fruit: large; quality good; red; matures late. Tree: medium height; very hardy; production heavy and reliable.

**Ember** *(Minnesota No. 83)* — Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1936. Shiro x South Dakota no. 33; cross made in 1913, selected in 1918. Fruit: matures late; high dessert and culinary quality; will keep for 2 to 3 weeks after ripening.

**Flaming Delicious.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1934. Patent no. 14; April 15, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown. Fruit: flesh red; freestone; early maturing. Tree: heavy bearer; hardy.

*Florida.*— See **Red Ace.**

**Golden Rod** *(Minnesota No. 120)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. Shiro x Howard's Yellow *(Prunus americana)*; cross made in 1913; selected in 1920. Fruit: large; yellow; firm. No longer recommended because it is a very shy bearer.

**Great Yellow.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1920. Fruit: yellow; freestone; flavor mild; quality good; large; matures early. Tree: hardy.

**Hennepin** *(Minnesota No. 132)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. Satsuma x *Prunus americana*; cross made in 1911, selected about 1918. Fruit: flesh red; good preserving quality. Tree: hardy; very productive.

**Honeymoon.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri. Green Gage x an unknown variety; selected in 1920. Fruit: golden yellow; large; quality high; midseason; most nearly resembles known parent.

**June Redskin.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1934. Patent no. 12; April 5, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1922. Fruit: flesh yellow, acid to sweet; skin red; round; season early, June 25 at Sebastopol.

**La Crescent** *(Minnesota No. 109)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. Shiro x Howard's Yellow *(Prunus americana)*; cross made in 1913; selected in 1919. Fruit: small; yellow; good dessert quality.

**Mammoth Cardinal.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1934. Patent no. 16; May 10, 1932; assigned to Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1919. Fruit: skin red; flesh yellow; clingstone; large; quality high; ships well; ripens July 14 at Sebastopol; similar if not identical with Formosa.

**Mendota** *(Minnesota No. 5)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1924. Burbank x Wolf; cross made in 1908; selected about 1912. Fruit: large; quality good.

*Minnesota No. 5.*— See **Mendota.**
*Minnesota No. 8.*— See **Elliot.**
*Minnesota No. 10.*— See **Waconia.**
*Minnesota No. 12.*— See **Red Wing.**
*Minnesota No. 17.*— See **Redcoat.**
*Minnesota No. 21.*— See **Tonka.**

*Minnesota No. 30.*— See **Winona.**
*Minnesota No. 50* — See **Mound.**
*Minnesota No. 83.*— See **Ember.**
*Minnesota No. 91.*— See **Underwood.**
*Minnesota No. 109.*— See **La Crescent.**
*Minnesota No. 116* — See **Newport.**
*Minnesota No. 118.*— See **Anoka.**
*Minnesota No. 120.*— See **Golden Rod.**
*Minnesota No. 132.*— See **Hennepin.**
*Minnesota No. 157* — See **Radisson.**
*Minnesota No. 194.*— See **Superior.**
*Minnesota No. 218.*— See **Pipestone.**

**Mound** *(Minnesota No. 50).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Burbank x Wolf; cross made in 1908. Fruit: medium red; flesh yellow; partly freestone. Tree: vigorous; hardy; very productive.

**Newport** *(Minnesota No. 116).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. Omaha x *Prunus pissardi.* An ornamental with purple foliage.

**Pipestone** *(Minnesota No. 218).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced for trial in 1928; introduced commercially in 1942. Burbank x *(Prunus salicina* x Wolf) ; cross made in 1919; fruited in 1926. Fruit: large; skin solid deep red, thin, tough but peeling easily; flesh yellow, somewhat stringy, with excellent quality; for home and commercial use. Tree: vigorous; hardy; performance reliable.

**Premier.**— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station (Paul H. Shepard). Introduced commercially in 1946. Burbank x Methley; selected in 1943. Fruit: extremely large; firm; red; suture shallow; flesh yellow; clingstone; juicy, tart, flavor good; seed small; skin tough; ripens August 1, with Burbank which it most nearly resembles.

**Purple Flame.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri; trademarked by this company. Parentage unknown; selected about 1922. Fruit: flesh red; quality good. Tree: foliage red; an ornamental variety.

**Radisson** *(Minnesota No. 157).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1925. *Prunus salicina* x *P. americana;* cross made in 1907 or 1908. Fruit · large; round; rich red with heavy bloom; flesh firm, yellow; semi-freestone; quality high.

**Red Ace** *(Florida).*— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri; trademarked by this company. Parentage unknown; selected about 1923. Most nearly resembles Elephant Heart. Fruit: flesh red; freestone; quality excellent. Tree: hardy; growth spreading; very productive.

**Redcoat** *(Minnesota No. 17).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in April, 1942. Burbank *(Prunus salicina)* x Wolf *(P. americana);* cross made in 1908. Fruit: freestone; skin crimson overlaid with a heavy bloom, thin, tender; flesh yellow, meaty, medium juicy; flavor sweet to mild, subacid, pleasant; season early, closely following Underwood; good canning and culinary qualities. Tree: productive; hardy; bears early.

**Red Wing** *(Minnesota No. 12).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Burbank x Wolf; cross made in 1908. Fruit: large; quality good; flesh firm, yellow.

**Sapalta.**— Originated at Brooks, Alberta, Canada, by the Canadian Pacific Railway in the spring of 1924. Introduced commercially in 1938 It was one of a lot of 1,000 seedlings secured from the Northwest Nursery Company, Valley City, North Dakota; probably a seedling of Sapa. Varietal name is a contraction of Alberta Sapa. Fruit: sand cherry; similar to Sapa but with tendency toward freestone condition; smaller seed with slight ridge on each side. Tree: bush habit, and difficult to distinguish from Sapa.

**Superior** *(Minnesota No. 194).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in January, 1933. Burbank x Kaga; selected in 1925. Fruit: early; large; firm; quality superior. Tree: prolific bearer; vigorous.

**Tonka** *(Minnesota No. 21).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Burbank x Wolf; cross made in 1908. Fruit: large; quality high. Tree: heavy and reliable producer, but short-lived.

**Underwood** *(Minnesota No. 91).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Shiro x Wyant; cross made in 1911; selected in 1916. Fruit: dull red; quality good. Tree: vigorous; heavy bearer.

**Waconia** *(Minnesota No. 10).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1923. Burbank x Wolf; cross made in 1908; selected in 1914. Tree: uniformly productive; hardy; quality fair. This variety is no longer propagated.

**Winona** *(Minnesota No. 30).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. *Prunus salicina* x *P. americana;* cross made in 1909 or 1910. Fruit: medium large; quality good; sweet. Tree: large; vigorous.

## Plumcot

**Orange.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri. Parentage unknown; selected about 1922. Fruit: skin yellow with reddish purple cheek; flesh yellow; quality good; flavor subacid.

**Purple.**— Originated in Sebastopol, California, by Luther Burbank. Introduced commercially in 1931 by Stark Brothers Nurseries, Louisiana, Missouri; trademarked by this company. Parentage unknown, discovered about 1922. Fruit: skin purple, slightly pubescent, with heavy bloom; flesh deep purple; clingstone; quality good.

## Raspberry

**Chief** *(Minnesota No. 223).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in May, 1930. Latham x self; selected in 1920. Fruit: early; quality good. Bush: hardy; vigorous.

**Latham** *(Minnesota No. 4).*— Originated in Excelsior, Minnesota by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. King x Louden; cross made in 1908; selected in 1914. Fruit: quality high. Bush: hardy; productive; markedly tolerant of mosaic.

*Minnesota No. 4.*— See **Latham.**

*Minnesota No. 223.*— See **Chief.**

*New York No. 17438.*— See **September.**

**September** *(New York No. 17438).*— Originated in Geneva, New York, by the New York State Agricultural Experiment Station (George L. Slate). Introduced commercially in the fall of 1947. Marcy x Ranere; cross made in 1934; selected for second test in 1939. Fruit: bright red; firm; size medium; fruitlets do not crumble; quality of summer crop is only fair, but the autumn berries are considered good in quality; summer crop is as early as that of Indian Summer and June or about 5 days earlier than Newburgh; fall crop matures 2 to 4 weeks before that of Indian Summer; principal fault is the tendency of the berries, especially of the summer crop, to cling to the bushes rather more tightly than is desirable in a commercial berry. Bush: vigorous; increases rapidly; hardy at Geneva; crops well; reaction to mosaic not known.

## Strawberry

**Arrowhead** *(Minnesota No. 1118).*— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in

November, 1946. Duluth x Senator Dunlap; selected in 1929. Plant: hardy; vigorous; forms many runners; flowers perfect. Fruit: firm enough to stand shipping.

**Chaska** *(Minnesota No. 801)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. (Dunlap x Pocomoke) x Brandywine. Fruit: large; showy; firm; good canner; high yielder. Variety no longer propagated.

**Deephaven** *(Minnesota No. 41)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Parentage unknown; selected in 1919. Fruit: large. Plant: everbearing; productive. Variety no longer propagated.

**Duluth** *(Minnesota No. 1017)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Pan American x Dunlap; cross made in 1909; selected in 1913. Fruit: dark red; quality good. Plant: adapted to heavy soils; vigorous; everbearer.

**Easy Picker** *(Minnesota No. 775)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Dunlap x Crescent. Fruit: quality good; flesh dark red. Plant productive

**Evermore** *(Minnesota No. 1166)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in February, 1945. Duluth x Senator Dunlap; selected in 1929. Plant: everbearer; productive; hardy; drought resistant.

**Fairland**.— Originated in Beltsville, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1947. Aberdeen x Fairfax; selected in 1938. Fruit: firmer and with better flavor than either Howard 17 or Catskill. Plant: resistant to red stele; very productive.

**Minnehaha** *(Minnesota No. 935)* — Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Minnesota x Abington; cross made in 1911. Fruit: large; firm; wedge-shaped; ships very well; late season. Variety no longer propagated.

**Minnesota** *(Minnesota No. 3)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1920. Dunlap x Pocomoke; cross made in 1907. Fruit: attractive; high quality. Plant: productive; subject to mosaic disease (June yellows).

*Minnesota No. 3*.— See **Minnesota**.
*Minnesota No. 41*.— See **Deephaven**.
*Minnesota No. 489*.— See **Nokomis**.
*Minnesota No. 775*.— See **Easy Picker**.
*Minnesota No. 801*.— See **Chaska**.
*Minnesota No. 935*.— See **Minnehaha**.
*Minnesota No. 1017*.— See **Duluth**.
*Minnesota No. 1118*.— See **Arrowhead**.
*Minnesota No. 1166*.—See **Evermore**.

**Nectarena**.— Originated in Thornhill, Ontario, Canada, by Matthew James Johnson. Introduced commercially in January, 1947. Patent no. 780; January 20, 1948; assigned to the R. M. Kellogg Company, Three Rivers, Michigan. Howard 17 x Bedarena; selected about 1940. Fruit: flavor sweet and mild, similar to Bedarena. Plant: vigor and productiveness similar to that of Howard 17.

**Nokomis** *(Minnesota No. 489)*.— Originated in Excelsior, Minnesota, by the University of Minnesota Fruit Breeding Farm. Introduced commercially in 1922. Dunlap x Abington; selected in 1918. Fruit: large; flavor good. Plant: drought resistant. Variety no longer propagated.

## TUNG

**Cooter** *(USDA No. F-4)*.— Originated in Brooker, Florida, by the United States Department of Agriculture. Introduced commercially in 1948. Parentage unknown; original tree was planted in January, 1931, in the orchard of H. W. Bennett near Brooker, Florida. Fruit: size medium; spherical, sometimes slightly oblate; borne in small clusters; oil content intermediate; matures early. Tree: productivity very high; moderately cold resistant.

**Gahl** *(USDA No. L-51)*.— Originated in Isabel, Louisiana, by the United States Department of Agriculture. Introduced commercially in 1948. Parentage unknown; original tree located in an orchard planted about 1928 by the Great Southern Lumber Company near Isabel, Louisiana. Fruit: large; borne singly or in small clusters; almost spherical except for tip of apex; percentage of kernel medium; oil content medium high; matures early. Tree: productivity very high; resistant to cold injury.

**Isabel** *(USDA No. L-2)*.— Originated in Isabel, Louisiana, by the United States Department of Agriculture. Introduced commercially in 1948. Parentage unknown; original tree is located in an orchard planted about 1928 by the Great Southern Lumber Company, near Isabel, Louisiana. Fruit: large; borne singly or in small clusters; rather prominently ridged at sutures; kernel percentage high; oil content very high; matures early. Tree: productivity very high; moderately resistant to cold injury.

**La Crosse** *(USDA No. F-99)*.— Originated in Brooker, Florida, by the United States Department of Agriculture. Introduced commercially in 1948. Parentage unknown; original tree planted in January, 1931, in the orchard of H. W. Bennett, near Brooker, Florida. Fruit: small; length shorter than breadth; flattened at apical and basal ends; cluster type; matures late; oil content high. Tree: productivity very high; top moderately dense with fruiting wood throughout.

**Lamont** *(USDA No. F-542)*.— Originated in Lamont, Florida, by the United States Department of Agriculture. Introduced commercially in 1948. Parentage unknown; original tree located in the Chase orchard near Lamont, Florida, and planted about 1931. Fruit: size medium to large: slightly flattened at apical end; frequently one fruit in each cluster is small and abnormal in shape; cluster medium type; percentage of kernel high; oil content high; matures in midseason. Tree: productivity very high; moderately resistant to cold injury.

*U.S.D.A. No. F-4*.— See **Cooter.**
*U.S.D.A. No. F-99*.— See **La Crosse.**
*U.S.D.A. No. F-542*.— See **Lamont.**
*U.S.D.A. No. L-2*.— See **Isabel.**
*U.S.D.A. No. L-51*.— See **Gahl.**

## NAMES OF PATENTED VARIETIES

| Patent Number | Varietal Name |
|---|---|
| 12 | June Redskin, plum |
| 14 | Flaming Delicious, plum |
| 16 | Mammoth Cardinal, plum |
| 41 | Honey Heart, cherry |
| 661 | Flamingo, peach |
| 724 | Wickson, apple |
| 728 | Devoe, pear |
| 741 | Max-Red Bartlett, pear |
| 751 | Sun Glo, apricot |
| 759 | Stark Early Flame, nectarine |
| 764 | Meyer, cherry |
| 780 | Nectarena, strawberry |
| 782 | Sanderson Special, grape |
| 787 | Pioneer, nectarine |
| 794 | Jongrimes, apple |
| 795 | Royal Fay, peach |

## ALPHABETICAL LIST OF VARIETY NAMES INCLUDED IN LIST NO. 4

Minnesota No. 10, plum
  See Waconia
Minnesota No. 12, plum
  See Red Wing
Minnesota No. 17, plum
  See Redcoat
Minnesota No. 21, plum
  See Tonka
Minnesota No. 30, plum
  See Winona
Minnesota No. 41, strawberry
  See Deephaven
Minnesota No. 43, gooseberry
  See Como
Minnesota No. 45, grape
  See Red Amber
Minnesota No. 50, plum
  See Mound
Minnesota No. 66, grape
  See Moonbeam
Minnesota No. 69, grape
  See Blue Jay
Minnesota No. 70, currant
  See Cascade
Minnesota No. 83, plum
  See Ember
Minnesota No. 90, apple
  See Haralson
Minnesota No. 91, plum
  See Underwood
Minnesota No. 109, plum
  See La Crescent
Minnesota No. 116, plum
  See Newport
Minnesota No. 118, plum
  See Anoka
Minnesota No. 120, plum
  See Golden Rod
Minnesota No. 132, plum
  See Hennepin
Minnesota No. 144, cherry plum
  See Nicollet
Minnesota No. 145, cherry plum
  See St. Anthony
Minnesota No. 157, plum
  See Radisson
Minnesota No. 158, grape
  See Bluebell
Minnesota No. 194, plum
  See Superior
Minnesota No. 207, apple
  See Wedge
Minnesota No. 218, plum
  See Pipestone
Minnesota No. 223, raspberry
  See Chief
Minnesota No. 237, apple
  See Folwell
Minnesota No. 240, apple
  See Chestnut
Minnesota No. 300, apple
  See Minnehaha
Minnesota No. 423, apple
  See Beacon
Minnesota No. 489, strawberry
  See Nokomis
Minnesota No. 635, apple
  See Flame
Minnesota No. 638, apple
  See Redwell
Minnesota No. 700, apple
  See Minjon
Minnesota No. 775, strawberry
  See Easy Picker
Minnesota No. 801, strawberry
  See Chaska
Minnesota No. 935, strawberry
  See Minnehaha
Minnesota No. 1007, apple
  See Prairie Spy
Minnesota No. 1017, strawberry
  See Duluth
Minnesota No. 1118, strawberry
  See Arrowhead
Minnesota No. 1166, strawberry
  See Evermore
Moonbeam, grape
Mound, plum
Nectarena, strawberry
Newport, plum
New York No. 17438, raspberry
  See September
Nicollet, cherry plum
Nokomis, strawberry
Orange, plumcot
Parker, pear
Pioneer, nectarine
Pipestone, plum
Prairie Spy, apple
Premier, plum
Purple, plumcot
Purple Flame, plum
Radisson, plum
Red Ace, plum
Red Amber, grape
Redcoat, plum
Red McIntosh, apple
Red Melba, apple
Redwell, apple
Red Wing, plum
Reliable, apricot
Royal Fay, peach
Ruby, grape
St. Anthony, cherry plum
Sanderson Special, grape
Sapalta, plum
September, raspberry
Sparkle, cherry
Spartan, apple
Spotlight, peach
Stark Early Flame, nectarine
Sun Glo, apricot
Superior, peach
Superior, plum

# MEMBERSHIP ROLL

AAMLID, KAARE........................University of Idaho, Moscow, Idaho.
ABMEYER, ERWIN..........Northeast Kansas Exp. Fields, Wathena, Kansas.
ACKER, R. M...............................5920 S. Madison, Hinsdale, Ill.
ACKLEY, W. B....................Washington State College, Pullman, Wash.
ADAMSON, R. M.......Dominion Experiment Sta., Saanichton, B. C., Canada.
ADRIANCE, G. W...............Texas A & M College, College Station, Texas.
AGGEN, A. F...................................Box 260, Camarillo, Calif.
AGNEW, E. L..........................7700 Market St., Youngstown, Ohio.
AKENHEAD, D.........Commonwealth Bureau, East Malling, Kent, England.
ALBAN, E. K.........................Ohio State University, Columbus, Ohio.
ALBEN, A. O............................606 Court House, Shreveport, La.
ALDERMAN, D. C........................Rainwater Annex Bldg., Ruston, La.
ALDERMAN, W. H...................University of Minnesota, St. Paul, Minn.
ALDRICH, W. W.................American Fruit Growers, Hagerstown, Md.
ALEXANDER, T. R.........................University of Miami, Miami, Fla.
ALLEN, A. G..............................W. F. Allen Co., Salisbury, Md.
ALLEN, F. W.........................University of California, Davis, Calif.
ALLEN, H. T..........Department of Agriculture, Lacombe, Alberta, Canada.
ALLEN, R. C..................................Box 687, Harrisburg, Pa.
ALLISON, C. K.........................Hanover Canning Co., Hanover, Pa.
ALLMENDINGER, D. F..................202 Court House, Vancouver, Wash.
ALLWRIGHT, W. J...................P. O. Box 1158, Pretoria, South Africa.
AMERINE, M. A.......................University of California, Davis, Calif.
AMSTEIN, W. G.....................Kansas State College, Manhattan, Kans.
ANAGNOSTOPOULOS, P. T............Superior School of Agr., Athens, Greece.
ANDERSEN, EMIL........University of Manitoba, Winnipeg, Manitoba, Canada.
ANDERSEN, E. M.........................Utah State College, Logan, Utah.
ANDERSON, F. W..........................826 22nd Street, Merced, Calif.
ANDERSON, M. S.....................Plant Industry Station, Beltsville, Md.
ANDERSON, OTTO..........Escola Sup. de Agr., Sicesa, Minas Gerais, Brazil.
ANDERSON, R. C..................University of Tennessee, Knoxville, Tenn.
ANDERSON, W. S...............Mississippi State College, State College, Miss.
ANDRUS, C. F...........................P. O. Box 844, Charleston, S. C.
ANSTEY, T. H....................University of Minnesota, St. Paul, Minn.
ANTHONY, R. D..............Pennsylvania State College, State College, Pa.
ANTLE, G. G. ..................Oklahoma A & M College, Stillwater, Okla.
APP, FRANK............................Seabrook Farms, Bridgeton, N. J.
APPLE, S. B., JR..................Washington State College, Pullman, Wash.
ARKELL, W. C..........................10 East 40th St., New York, N. Y.
ARMSTRONG, J. A..........................307 West 6th St., Ontario, Calif.
ARMSTRONG, W. D..................University of Kentucky, Princeton, Ky.
ASEN, SAM................New Jersey Agr. Exp. Sta., New Brunswick, N J.
*ATTIA, M. S............................Cornell University, Ithaca N. Y.
AUCHTER, E. C.....................Pineapple Research Inst., Honolulu, T. H.
AUSTIN, LLOYD............Rainbow Hybridizing Gardens, Placerville, Calif.

BABB, M. F......................Alaska Experiment Sta., Palmer, Alaska.
BAHGAT, M.............Ministry of Agriculture, 11 Khateeb St., Giza, Egypt.
BAILEY, J. S....................University of Massachusetts, Amherst, Mass.
BAILEY, R. M......................Maine Experiment Sta., Orono, Maine.
BAILEY, W. K.................Georgia Experiment Station, Experiment, Ga.
BAIRD, W. P..........................U. S. Field Station, Mandan, N. D.
BAKER, R. E.........................University of California, Davis, Calif.
BALCH, W. B........................1160 Vancouver Ave., Burlingame, Calif.
BALDWIN, H. E., JR........................Bayberry Lane, Westport, Conn.
BALLARD, J. C...........................Cornell University, Ithaca, N. Y.
BANTA, E. S...........................................Lebanon, Ohio.
BARHAM, W. S...........................Cornell University, Ithaca, N. Y.

*Life members.

Barnard, J. D. . . . . . . . . . . . . . . Minnesota Valley Canning Co., Le Sueur, Minn.
Barnes, W. C. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 158, Charleston, S. C.
Barnett, R. J. . . . . . . . . . . . . . . . . . . . . . Kansas State College, Manhattan, Kan.
Barr, C. G. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 840, Lansing, Mich.
Barrett, H. C. . . . . . . . . . . . . . . . . . . . . . . . . University of Illinois, Urbana, Ill.
Barrons, K. C. . . . . . . . . . . . . . . . . . . . . . . . 133 Durand St., East Lansing, Mich.
Barss, A. F. . . . . . . . . . . Univ. of British Columbia, Vancouver, B. C., Canada.
Bass, I. H. . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bass Pecan Co., Lumberton, Miss.
Batcheller, O. A. . . . . . . . . . . California Polytechnic School, San Dimas, Calif.
Batchelor, L. D. . . . . . . . . . . . . . . . . . Citrus Experiment Sta., Riverside, Calif.
Batjer, L. P. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 99, Wenatchee, Wash.
Batson, F. S. . . . . . . . . . . . . . . . . . Mississippi State College, State College, Miss.
Baudonnet, P. E. . . . . . . . . . . . . . . . . . . . . . . . . . . 302 E. Street, Davis, Calif.
Baur, Karl . . . . . . . . . . . . . . . Western Wash. Experiment Sta., Puyallup, Wash.
Beach, G. A. . . . . . . . . . . . . . . . Colorado Agricultural College, Ft. Collins, Colo.
Beach, G. W. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1414 Brassie, Flossmoor, Ill.
Beames, G. H. . . . . . . . . . . . . . . . . . . . . . 12 Flagstaff Hill Terrace, Canton, Mass.
Beattie, J. H. . . . . . . . . . . . . . . . . . . . . . . Plant Industry Station, Beltsville, Md.
Beattie, J. M. . . . . . . . . . . . . . . . . . . . . . . . Ohio Experiment Sta., Wooster, Ohio.
Beatty, R. H. . . . . . . . . . . . . . . . . . American Chemical Paint Co., Ambler, Pa.
Beaumont, J. H. . . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 18, Honolulu, Hawaii.
Beck, Gail . . . . . . . . . . . . . . . . . . . . . . . . . 230 Gunson Street, East Lansing, Mich.
Beckenbach, J. R. . . . . . . . . . . . . . . . . . Vegetable Crops Lab., Bradenton, Fla.
Becnel, I. J. . . . . . . . . . . . . . . . . . . 1804 American Bank Bldg., New Orleans, La.
Beecher, F. S. . . . . . . . . . . . . . . . . 5521 Colorado Ave., N. W., Washington, D. C.
Beglau, R. A. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 430 N. 15th St., Corvallis, Ore.
Bell, H. P. . . . . . . . . . . . . . . . . . . Dalhousie University, Halifax, N. S., Canada.
Bemis, W. P. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 241 B. Street, Davis, Calif.
Bender, E. K. . . . . . . . . . . . . . . . . . University of Maryland, College Park, Md.
Bennett, J. P. . . . . . . . . . . . . . . . . . . . University of California, Berkeley, Calif.
Beresford, B. C. . . . . . . . . . . . . . . . University of Minnesota, Crookston, Minn.
Berry, J. B. . . . . . . . . . . . . . . . . . . . . . . . . 332 Avenue E, S. E., Winter Haven, Fla.
Bhandall, B. S. . . . . . . . . . . . . . . . . . . . . . . . . . Govt. of India, New Delhi, India.
Biale, J. B. . . . . . . . . . . . . . . . . . . . . University of California, Los Angeles, Calif.
Biebel, J. P. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 312 N. 4th Road, S. Miami, Fla.
Biekart, H. M. . . . . . . . . . . . . . . . . . Rutgers University, New Brunswick, N. J.
Binkley, A. M. . . . . . . . . . . . . . . Colorado Agricultural College, Ft. Collins, Colo.
Birkeland, C. J. . . . . . . . . . . . . . . . . . . . . . . . . . . . 818 W. Vine Street, Urbana, Ill.
Blackburn, H. W. . . . . . . . . . . . . . . . . . . P. O. Box 24, Elgin C. P., South Africa.
Blackhurst, H. T. . . . . . . . . . . Texas A & M College, College Station, Texas.
Blaha, Joseph . . . . . . . . . . . . . . . . . . . . . . . . . . Brno, Zemedelska, Czechoslovakia.
Blair, J. C. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 57, Urbana, Ill.
Blanchard, J. L. . . . . . . . . . . Missouri State Teachers' College, Kirksville, Mo.
Blasberg, C. H. . . . . . . . . . . . . . . . . . . . . . University of Vermont, Burlington, Vt.
Bligh, R. D. L. . . . . . . . . . . . . Experimental Station, Kentville, N. S., Canada.
Blodgett, C. O. . . . . . . . . . . . . . . . . . . 529 Hathway Ave., San Luis Obispo, Calif.
Blodgett, R. L. . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 978, Idaho Falls, Idaho.
Bluhm, Carolyn R. . . . . . . . . . . . . . . . . . . . . . University of Illinois, Urbana, Ill.
Bobb, A. C. . . . . . . . . . . . . . . . . . . . . . . . . University of Connecticut, Storrs, Conn.
Boerner, E. S. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 266, Newark, N. Y.
Boller, C. A., Jr. . . . . . . . . . . . . . . . . . . . . . . Oregon State College, Corvallis, Ore.
Booye, B. T. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 125, Sunnyvale, Calif.
Boswell, V. R. . . . . . . . . . . . . . . . . . . . . . . Plant Industry Station, Beltsville, Md.
Bouquet, A. G. B. . . . . . . . . . . . . . . . . . . . Oregon State College, Corvallis, Ore.
Bowles, E. J. . . . . . . . . . . . . . . . . . . . . . . . . 201 Post Office Bldg., San Jose, Calif.
Boyd, J. H. . . . . . . . . . . . . . . . . . . Pennsylvania State College, State College, Pa.
Boyd, L. Q. . . . . . . . . . . . . . . . . . . . . . . . . . 6253 Van Buren Ave., Hammond, Ind.
Boyd, W. I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 15, Wyoming, Del.
Boynton, Damon . . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
Braathen, E. H. . . . . . . . . . . . . . . . . . . . Box 613, Prince George, B. C., Canada.
Bradford, F. C. . . . . . . . . . . . . U. S. Plant Introduction Garden, Glenn Dale, Md.
Bradley, R. H. . . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.

BRASE, K. D. . . . New York State Experiment Sta., Geneva, N. Y.
BRASHER, E. P. . . . University of Delaware, Newark, Del.
BRAUN, O. M. . . . R 1, Box 230, Sanger, Calif.
BREGGER, J. T. . . . Box 952, Clemson, S. C.
BRIERLEY, PHILIP . . . Plant Industry Station, Beltsville, Md.
BRIERLEY, W. G. . . . University of Minnesota, St. Paul, Minn.
BRIGHTWELL, W. T. . . . Georgia Coastal Plain Experiment Station, Tifton, Ga.
BRISON, F. R. . . . Texas A & M College, College Station, Texas.
BRITTINGHAM, W. H. . . . Texas Experiment Station, College Station, Tex.
BROOKS, R. M. . . . University of California, Davis, Calif.
BROWN, D. S. . . . Hawaiian Pineapple Co., Honolulu, Hawaii.
BROWN, H. D. . . . Ohio State University, Columbus, Ohio.
BROWN, J. G. . . . University of California, Davis, Calif.
BROWN, K. E. . . . R. D. 2, Lyons, N. Y.
BROWN, R. T. . . . Plaquemine Parish Experiment Sta., Diamond, La.
BROZDOWSKI, J. J., JR. . . . 8 Wisner Terrace, Goshen, N. Y.
BRYAN, O. C. . . . Box 156, Florida Southern College, Lakeland, Fla.
BRYANT, L. R. . . . Washington State College, Pullman, Wash.
BRYANT, M. D. . . . Texas Sub-Station No. 17, Ysleta, Texas.
BULLARD, E. T. . . . Purdue University, Lafayette, Ind.
BULLOCK, R. M. . . . Tree Fruit Experiment Sta., Wenatchee, Wash.
BURKHOLDER, C. L. . . . Purdue University, Lafayette, Ind.
BURRELL, A. B. . . . 707 Mitchell St., Ithaca, N. Y.
BURROWS, F. W. . . . International Apple Association, Rochester, N. Y.
BUSHEY, D. J. . . . Cornell University, Ithaca, N. Y.
BUSHNELL, JOHN . . . Ohio Experiment Sta., Wooster, Ohio.
BUTTERFIELD, N. W. . . . 240 Beaver St., Waltham, Mass.
BYERS, EARL . . . Dixie Orchard Co., Vincennes, Ind.

CAIN, J. C. . . . New York State Experiment Sta., Geneva, N. Y.
CAIN, R. F. . . . Texas A and M College, College Station, Texas.
CALDIS, P. D. . . . 101 California St., San Francisco, Calif.
CALDWELL, J. S. . . . Plant Industry Station, Beltsville, Md.
CAMERON, S. H. . . . University of California, Los Angeles, Calif.
CAMP, A. F. . . . Citrus Experiment Sta., Lake Alfred, Fla.
*CAMP, W. B., JR. . . . R. 1, Box 500, Bakersfield, Calif.
CAMPBELL, J. A. . . . Truck Corps Experiment Sta., Crystal Springs, Miss.
CAMPBELL, R. W. . . . Kansas State College, Manhattan, Kans.
CANNON, O. S. . . . Utah Agricultural Experiment Sta., Logan, Utah.
CARDIFF, I. D. . . . Cardiff & Co., Yakima, Wash.
CAREW, JOHN . . . Cornell University, Ithaca, N. Y.
CARDINELL, H. A. . . . Michigan State College, East Lansing, Mich.
CARLETON, R. M. . . . 601 W. Jackson Blvd., Chicago, Ill.
CARLSON, R. F. . . . Michigan State College, East Lansing, Mich.
CAROLUS, R. L. . . . Michigan State College, East Lansing, Mich.
CARSTENS, M. W. . . . Northwestern Wash. Experiment Sta., Mt. Vernon, Wash.
CASSERES, E. H. . . . Inter-American Inst. of Agr. Sci., Turrialba, Costa Rica.
CAULFIELD, L. R. . . . R. 1, Kasson, Minn.
CHADWICK, L. C. . . . Ohio State University, Columbus, Ohio.
CHAN, A. P. . . . Central Experiment Farm, Ottawa, Canada.
CHANDLER, F. B. . . . East Wareham, Mass.
CHANDLER, W. H. . . . 405 Hilgard Ave., Los Angeles, Calif.
CHANG, W.-T. . . . Lingnan University, Canton, China.
CHAPLIN, C. E. . . . University Farm, Olney, Ill.
CHAPPELL, W. E. . . . Plant Industry Station, Beltsville, Md.
CHARLES, F. M. . . . 145 S. American St., Stockton, Calif.
CHASE, S. B. . . . Forest Products Section T. V. A., Norris, Tenn.
CHHONKAR, V. P. S. . . . Ohio State University, Columbus, Ohio.
CHILDERS, N. F. . . . Rutgers University, New Brunswick, N. J.
CHILDS, W. H. . . . University of West Virginia, Morgantown, W. Va.
CHRIST, E. G. . . . New Jersey Experiment Sta., New Brunswick, N. J.
CHOO, T.-F. . . . University of Minnesota, St. Paul, Minn.

Christopher, E. P.............Rhode Island State College, Kingston, R. I.
Cintron, R. H..................................Box 473, Mercedes, Tex.
Clark, B. E...............New York State Experiment Sta., Geneva, N. Y.
Clarke, A. E.....................Utah State Experiment Sta., Logan, Utah.
Clarke, J. H.........................Cranguyma Farm, Long Beach, Wash.
Clarke, J. R............................J. R. Clarke & Son, Milton, N. Y.
Clarke, W. S., Jr............................Box 167, State College, Pa.
Clay, H. F.........................University of Hawaii, Honolulu, T. H.
Clegg, H. H................................105 N. 10th St., Lafayette, Ind.
Clore, W. J..............Irrigation Branch Experiment Sta., Prosser, Wash.
Close, A. W..............U. S. Plant Introduction Garden, Glenn Dale, Md.
Cochran, F. D................University of North Carolina, Raleigh, N. C.
Cochran, G. W..........................Utah State College, Logan, Utah.
Cochran, H. L..........................Pomona Products Co., Griffin, Ga.
Cochran, L. C...................Citrus Experiment Sta., Riverside, Calif.
Cody, L. R..............................Vickery Avenue, Saratoga, Calif.
Cohen, Herman..........................................no address.
Colby, A. S...........................University of Illinois, Urbana, Ill.
Collins, C. M.......................P. O. Box 187, Halifax, N. S., Canada.
Collins, W. H.............................State House, Des Moines, Ia.
Combs, O. B.........................University of Wisconsin, Madison, Wis.
Comin, Donald.......................Ohio Experiment Sta., Wooster, Ohio.
Compton, Cecil......................Oregon State College, Corvallis, Ore.
Condit, I. A............................496 S. Howard St., Ventura, Calif.
Condit, I. J........................Citrus Experiment Sta., Riverside, Calif.
Cook, J. A.............................Cornell University, Ithaca, N. Y.
Cook, Solomon..........................Cornell University, Ithaca, N. Y.
Cooley, J. S.......................Plant Industry Station, Beltsville, Md.
Coombs, R. C...........................................Henniker, N. H.
Cooper, W. C.................................Box 241, Weslaco, Texas.
Cordner, H. B................Oklahoma A & M College, Stillwater, Okla.
Corman, H. E..............2200 St. Clair Ave. W., Toronto, Ont., Canada.
Cotton, R. H..................Holly Sugar Corp., Colorado Springs, Colo.
Cover, C. J., Jr........................Charter Seed Co., Twin Falls, Idaho.
Cowart, F. F....................Georgia Experiment Sta., Experiment, Ga.
Cowgill, W. H.................American Embassy, Guatemala City, C. A.
Cowley, W. R............Texas Experiment Sta., Box 461, Weslaco, Texas.
Cox, L. G.................................Box 82, Canajoharie, N. Y.
Cram, W. H......................University of Minnesota, St. Paul, Minn.
Crane, H. L........................Plant Industry Station, Beltsville, Md.
Crane, J. C..........................University of California, Davis, Calif.
Croce, F. M..................Matienzo 339, San Jose, Mendoza, Argentina.
Crocker, Wm.........................1086 N. Broadway, Yonkers, N. Y.
Cross, F. B...................Oklahoma A & M College, Stillwater, Okla.
Cruess, W. V....................University of California, Berkeley, Calif.
Culbert, J. R............................University of Illinois, Urbana, Ill.
Culbertson, Ray........N. R. S., Agr. Div., APO 500, San Francisco, Calif.
Cullinan, F. P......................Plant Industry Station, Beltsville, Md.
Culpepper, C. W..................4435 N. Pershing Drive, Arlington, Va.
Cumming, Patrick.................University College, Dundee, Scotland.
*Cunningham, D. H...............Grabouw, C. P., Union of South Africa.
Currence, T. M..................University of Minnesota, St. Paul, Minn.
Curtis, L. C.........................618 Wilson Building, Dallas, Texas.
Curtis, O. F., Jr............New York State Experiment Sta., Geneva, N. Y.
Curtis, O. F., Sr........................Cornell University, Ithaca, N. Y.

Daigle, C. J..............................Box 1449, State College, Miss.
Dallas, J. E.......................................R. 3, Chardon, Ohio.
Danielson, L. L...........................P. O. Box 2160, Norfolk, Va.
Darrow, G. M......................Plant Industry Station, Beltsville, Md.
Darrow, W. H................................................Putney, Vt.
Dauro, V. A..........................3120 West Beach, Gulfport, Miss.

DAVENPORT, S. L......................9 Valley Hill Dr., Worcester, Mass.
DAVIDIS, U. X...............Superior School of Agriculture, Athens, Greece.
DAVIDSON, J. H.......................54 Elkenburg St., South Haven, Mich.
DAVIDSON, O. W.........New Jersey Experiment Sta., New Brunswick, N. J.
DAVIS, E. A.....Yale University, Osborn Botanical Lab., New Haven, Conn.
DAVIS, G. N..........................University of California, Davis, Calif.
DAVIS, HELEN I..........................11 Windsor Ave., Buffalo, N. Y.
DAVIS, L. D......................... University of California, Davis, Calif.
DAVIS, L. L......................Virginia Experiment Sta., Blacksburg, Va.
DAVIS, M. B..........Central Experimental Farm, Ottawa, Ontario, Canada.
DAVIS, V. H.............................245 N. High St., Columbus, Ohio
DAVIS, W. E.............................Box 1254, State College, Miss.
DEARBORN, C. H............New York State Experiment Sta., Geneva, N. Y.
DEARBORN, R. B...Eastern States Farmers' Exchange, West Springfield, Mass.
DE CHAUNAC, A...........T. G. Bright & Co., Niagara Falls, Ontario, Canada.
DEAN, L. L.............................Purdue University, Lafayette, Ind.
DECOU, S. C.........................................Merchantville, N. J.
DEGMAN, E. S...................U. S. Dept. Agr., Box 426, Medford, Ore.
DELWICHE, E. D..........................1140 Clark Way, San Jose, Calif.
DEMPSEY, A. H...................Georgia Experiment Sta., Experiment, Ga.
DENISEN, E. L...........................Iowa State College, Ames, Iowa.
DENNISON, R. A..................Florida Experiment Sta.,Gainesville, Fla.
DEONIER, M. T...............U. S. Horticultural Field Sta., Meridian, Miss.
DERMEN, HAIG......................Plant Industry Station, Beltsville, Md.
DETAR, J. E..........................University of California, Davis, Calif.
DETAR, V. W.....................................Box 1095, Fairfield, Calif.
DETJEN, L. R........................University of Delaware, Newark, Del.
DETWILER, S. B..........................1028 N. Daniel St., Arlington, Va.
DEWERTH, A. F..............Texas A & M College, College Station, Tex.
DEWEY, D. H.......................................Box 307, Fresno, Calif.
DHILLON, A. S.........................327 Mason Hall, East Lansing, Mich.
DIAS, M. S..................Box 187, Cary Hall East, West Lafayette, Ind.
DIAZ, J. R.............................3551 Juncal, Buenos Aires, Argentine.
DICKEY, R. D....................Florida Experiment Sta., Gainesville, Fla.
DICKINSON, B. C................Sherwin-Williams Co., Bound Brook, N. J.
DICKINSON, C. E........................1474 E. Long St., Columbus, Ohio.
DIDIER, E. F............................4603 W. State St., Rockford, Ill.
DIEHL, H. C.............................2082 Center St., Berkeley, Calif.
DIXON, J. L.....................................Box 71, Toppenish, Wash.
DODGE, F. N.......................................Lee Road, Covington, La.
DOLAN, DESMOND................Rhode Island State College, Kingston, R. I.
DONEEN, L. D........................University of California, Davis, Calif.
DORAN, W. L..................University of Massachusetts, Amherst, Mass.
DOUD, D. A..................1134 Northwestern Ave., West Lafayette, Ind.
DOUD, L. J...............................................R. 1, Wabash, Ind.
DOWD, O. J...........................P. O. Box No. 71, Paw Paw, Mich.
DRAIN, B. D..................Tennessee Experiment Sta., Knoxville, Tenn.
DRINKWATER, W. O................University of Connecticut, Storrs, Conn.
DROSDOFF, MATTHEW..........................Box 2817, Gainesville, Fla.
DRUEHL, W. C............California Packing Corp., Box 2109, Portland, Ore.
DUNN, B. F.......................................Box 498, Rochester, Minn.
DUNTON, R. C............................116 William St., Newark, N. Y.
DUSSAILLANT, ALEJANDRO......................................Lontue, Chile.
DUTTON, W. C.........................523 Bailey St., East Lansing, Mich.
DYE, H. W..............Niagara Sprayer & Chemical Co., Middleport, N. Y.

EALY, R. P....................Oklahoma A. & M. College, Stillwater, Okla.
EASTWOOD, T. M............................General Delivery, Delphi, Ind.
ECKERSON, SOPHIA H..............................Pleasant Valley, Conn.
EDGECOMBE, S. W........................University of Utah, Logan, Utah.
EDGERTON, L. J..........................Cornell University, Ithaca, N. Y.
EDMOND, J. B................Mississippi State College, State College, Miss.

Edwards, C. J....................P. O. Box 43, Stonewall, Manitoba, Canada.
Eggert, F. P..............................Cornell University, Ithaca, N. Y.
Eggert, Russell..............University of New Hampshire, Durham, N. H.
Einset, John..............New York State Experiment Sta., Geneva, N. Y.
Elle, G. O................................Cornell University, Ithaca, N. Y.
Ellenwood, C. W....................Ohio Experiment Sta., Wooster, Ohio.
Ellis, N. K..........................Purdue University, Lafayette, Ind.
Ellison, J. H............................Cornell University, Ithaca, N. Y.
Elwell, R. N.............................R. D. 50, Vineyard Haven, Mass.
Embleton, T. W........................Cornell University, Ithaca, N. Y.
Emmert, E. M....................University of Kentucky, Lexington, Ky.
Emsweller, S. L....................Plant Industry Station, Beltsville, Md.
Enzie, J. V..............New Mexico State College, State College, N. M.
Enzie, W. D...................Birds Eye-Snider Packing Co., Albion, N. Y.
Erwin, A. T...............................Iowa State College, Ames, Iowa.
Esty, J. R..........................322 Battery St., San Francisco, Calif.
Evans, Sterling.........................305 Delaware, Kansas City, Mo.
Ewing, Mrs. G. C.......................1205 Muirlands Dr., La Jolla, Calif.

Falkenberg, G. V......................Purdue University, Lafayette, Ind.
Farooqui, H. M...............................1312 S. Race St., Urbana, Ill.
Faslagic, Mehmedalija......Ministry of Agriculture, Gorazde, Jugoslavia.
Faust, F. B.................................P. O. Box 4264, Atlanta, Ga.
Fazio, Steve.........................University of Arizona, Tucson, Ariz.
Fellers, C. R..................University of Massachusetts, Amherst, Mass.
Ferguson, A. C..............Colorado A. and M. College, Ft. Collins, Colo.
Ficklin, W. C., Jr...........................R. 2, Box 84, Madera, Calif.
Filinger, G. A....................Kansas State College, Manhattan, Kans.
Fillmore, R. H.........................19 May St., Jamaica Plain, Mass.
Finch, J. R.............................................Bailey, N. C.
Findlen, Herbert........................Cornell University, Ithaca, N. Y.
Fischer, C. W., Jr.......................Cornell University, Ithaca, N. Y.
Fish, A. S.........................Kansas State College, Manhattan, Kans.
Fisher, Barrett.......................Westville Laboratories, Monroe, Conn.
Fisher, D. F..................U. S. Department of Agr., Washington, D. C.
Fisher, D. V........Dominion Experiment Sta., Summerland, B. C., Canada.
Fisher, E. G.............................Cornell University, Ithaca, N. Y.
Fisher, V. J..................Michigan State College, East Lansing, Mich.
Fleming, H. K................Erie Co. Field Research Lab., North East, Pa.
Floate, Ray..................Michigan Fruit Canners, Benton Harbor, Mich.
Flory, W. S., Jr.......................University of Virginia, Boyce, Va.
Fogle, H. W......................University of Minnesota, St. Paul, Minn.
Foley, R. F..................University of New Hampshire, Durham, N. H.
Ford, H. W........................Ohio State University, Columbus, Ohio.
Forde, H. I.........................University of California, Davis, Calif.
Forsee, W. T., Jr............Everglades Experiment Sta., Belle Glade, Fla.
Foskett, R. L...........................Iowa State College, Ames, Iowa.
Fosler, G. M..........................University of Illinois, Urbana, Ill.
Fossum, M. T...........................Cornell University, Ithaca, N. Y.
Foster, A. A..........Long Island Agr. and Tech. Inst., Farmingdale, N. Y.
Francis, J. G.........................516 N. Center St., Mt. Olive, N. C.
Franklin, D. F....................Idaho Experiment Sta., Parma, Idaho.
Frazier, W. A....................University of Hawaii, Honolulu, Hawaii.
French, A. P..................University of Massachusetts, Amherst, Mass.
Friend, W. H.................................Box 295, Weslaco, Texas.
Fry, B. O.....................Georgia Experiment Station, Experiment, Ga.
Fueglein, J. B.........................Joseph H. Hill Co., Richmond, Ind.
Furr, J. R...................................P. O. Box 737, Indio, Calif.

Gabelman, W. H......................P. O. Box 1106, New Haven, Conn.
Galle, F. C.....................University of Tennessee, Knoxville, Tenn.
Gardner, M. E................North Carolina State College, Raleigh, N. C.

GARRETT, J. M. .......................................R. 4, Versailles, Ky.
GARRISON, O. B. ..................South Carolina State College, Clemson, S. C.
GAUCH, H. G. ......................University of Maryland, College Park, Md.
GEISE, C. E. ..............................Iowa State College, Ames, Iowa.
GEISE, F. W. ............................104 S. Michigan Blvd., Chicago, Ill.
GELUWE, J. V. ...............................G.L.F. Service, Ithaca, N. Y.
GERBER, R. K. ............................Utah State College, Logan, Utah.
GERHARDT, FISK ..........................P. O. Box 99, Wenatchee, Wash.
GIANFAGNA, A. J. ...............Ornamental Research Lab., Farmingdale, L. I.
GIBBS, L. C. ................New Mexico State College, State College, N. M.
GILBERT, F. A. .............New Jersey State College, New Brunswick, N. J.
GILBERT, S. G. .........................Box 2817, Univ. Sta., Gainesville, Fla.
GILKESON, ANNA L. ...............1631 Euclild St., N. W., Washington, D. C.
GILL, D. L. .......................................Box 2217, Springhill, Ala.
GILMORE, A. E. .........................University of California, Davis, Calif.
GLENN, D. S. ...........................................Box 46, Exeter, Calif.
GNAUCK, DORIS MAE ...................4210 Wanetah Trail, Madison, Wis.
GOERTZEN, K. L. ..........................General Delivery, Blacksburg, Va.
GOODMAN, R. M. ...............University of New Hampshire, Durham, N. H.
GOPALKRISHNA, N. ......................University of Illinois, Urbana, Ill.
GOSPODARSTWA, S. G. ......Wiejskiego Zaklad Upwrawy 1, Warsaw, Poland.
GOSS, H. S. ....................................6545 Liberty St., Fresno, Calif.
GOSSARD, A. C. ..................U. S. Hort. Field Sta., R. 6, Meridian, Miss.
GOULD, W. A. .......................Ohio State University, Columbus, Ohio.
GRAMLING, MRS. A. C., JR. ..........................R. 2, Orangeburg, S C.
GRAY, G. F. ....................State Teachers' College, Nacogdoches, Texas.
GRAY, O. S. ......................................Box 513, Arlington, Texas.
GREEN, F. M. ...............Colorado Experiment Sta., Box 439, Austin, Colo.
GREENE, LAURENZ .........................Purdue University, Lafayette, Ind.
GREENLEAF, W. H. ...................Alabama Experiment Sta., Auburn, Ala.
GRIBBINS, M. F. ...........E. I. DuPont de Nemours & Co., Wilmington, Del.
GRIGGS, W. H. .........................University of California, Davis, Calif.
GROVE, L. C. ..............................Iowa State College, Ames, Iowa.
GUENGERICH, H. W. ......................901 Tennessee St., Louisiana, Mo.
GUNESCH, W. E. ................................1444 Wazee St., Denver, Colo.
GURGEL, JOSE T. A. ................Escola Superior de Agr., S. Paulo, Brazil.
GUYER, R. B. .....................University of Maryland, College Park, Md.
GWINN, A. B. ..............................Iowa State College, Ames, Iowa.

HAAS, A. R. C. ....................Citrus Experiment Sta., Riverside, Calif.
HABER, E. S. ..............................Iowa State College, Ames, Iowa.
HAGGAN, H. C. .............Morehead State Teachers' College, Morehead, Ky.
HAGLER, T. B. ..................Alabama Polytechnic Institute, Auburn, Ala.
HAIGHT, G. S. ......................311 South 2nd Street, Maquoketa, Iowa.
HALL, C. B. ...............................Cornell University, Ithaca, N. Y.
HALL, S. W. ............................University of Illinois, Urbana, Ill.
HALLER, M. H. ........................Plant Industry Station, Beltsville, Md.
HALMA, F. F. .......................405 Hilgard Avenue, Los Angeles, Calif.
HAMILTON, JOSEPH ...............................R. 1, Box 798, Yuma, Ariz.
HAMNER, C. L. ..................Michigan State College, East Lansing, Mich.
HAMNER, K. C. ..................University of California, Los Angeles, Calif.
HAMSON, A. R. ...........................Cornell University, Ithaca, N. Y.
HANCHEY, R. H. ...............Louisiana State University, Baton Rouge, La.
HANLEY, J. H. .................................Station KJR, Seattle, Wash.
HANNA, G. C. ..........................University of California, Davis, Calif.
HANSEN, C. J. ..........................University of California, Davis, Calif.
HANSEN, ELMER ........................Oregon State College, Corvallis, Ore.
HANSON, K. W. ...................University of Minnesota, St. Paul, Minn.
HARDENBURG, E. V. ......................Cornell University, Ithaca, N. Y.
HARDING, P. L. .........................415 N. Parramore St., Orlando, Fla.
HARDY, R. M. .....................University of Washington, Seattle, Wash.
HARGRAVE, P. D. ..............Provincial Hort. Sta., Brooks, Alberta, Canada.

HARLEY, C. P. ........................ Plant Industry Station, Beltsville, Md.
HARMON, F. N. ................................ 1742 S. Cedar, Fresno, Calif.
HARMON, S. A. .................. Coastal Plain Experiment Sta., Tifton, Ga.
HARN, E. J. ............................ P. O. Box 424 Oklahoma City, Okla.
HARNACK, R. E. .......................... University of Illinois, Urbana, Ill.
HARPER, R. E. ............ New Mexico State College, State College, N. M.
HARRINGTON, F. M. ................ University of Montana, Bozeman, Mont.
HARRINGTON, J. F. ...................... University of California, Davis, Calif.
HARRIS, R. W. ............................ Cornell University, Ithaca, N. Y.
HARRISON, T. B. ...... Dominion Experiment Sta., Harrow, Ontario, Canada.
HARTMAN, F. O. .................... Ohio State University, Columbus, Ohio.
HARTMAN, J. D. ............................ Cornell University, Ithaca, N. Y.
HARTMANN, H. T. .................... University of California, Davis, Calif.
HARVEY, E. M. ............................ 7 Federal Bldg., Pomona, Calif.
HASEK, R. F. ...................... Ohio State University, Columbus, Ohio.
HASSAN, H. H. .......................... University of Illinois, Urbana, Ill.
HAUGE, A. G. ........................ 505 Fairmont Ave., Fairmont, W. Va.
HAUN, J. R. ...................... University of Maryland, College Park, Md.
HAUT, I. C. ...................... University of Maryland, College Park, Md.
HAVIS, J. R. ............................ Cornell University, Ithaca, N. Y.
HAVIS, LEON ........................ Plant Industry Station, Beltsville, Md.
HAWES, J. E. .................... University of Maryland, College Park, Md.
HAWTHORN, LESLIE R. .................. Utah Experiment Sta., Logan, Utah.
HAWTHORNE, P. L. ............ Louisiana State University, Baton Rouge, La.
HAYWARD, H. D. .................... Regional Salinity Lab., Riverside, Calif.
HAZLEWOOD, HARRY ................ P. O. Box 1, Epping, New South Wales.
HEATON, C. R. ................ Heart of E. Texas, Agr. Council, Tyler, Tex.
HECHLER, CHAS., JR. .......................... P. O. Box 304, Roslyn, N. Y.
HEDLIN, W. A. ............................ Cornell University, Ithaca, N. Y.
HEICK, ANNA E. ...................... School of Horticulture, Ambler, Pa.
HEINICKE, A. J. ............ New York State Experiment Sta., Geneva, N. Y.
HEINZE, P. H. ........................ Plant Industry Station, Beltsville, Md.
HEMPHILL, D. D. .................... University of Missouri, Columbia, Mo.
HENDRICKSON, A. H. .................. University of California, Davis, Calif.
HENDRIX, J. W. .................... University of Hawaii, Honolulu, Hawaii.
HEPLER, J. R. ................ University of New Hampshire, Durham, N. H.
HERMAN, J. R. ...................... 1160 Cragmont Avenue, Berkeley, Calif.
HERNANDEZ, T. P. ................ Louisana State College, Baton Rouge, La.
HESSE, C. O. .......................... University of California, Davis, Calif.
HESTER, J. B. .......................... Campbell Soup Co., Riverton, N. J.
HEWETSON, F. N. .............. Pennsylvania State College, Arendtsville, Pa.
HEWETT, W. B. ...................... University of California, Davis, Calif.
HIKIDA, R. H. ........ University of Manitoba, Winnipeg, Manitoba, Canada.
HILDEBRAND, E. M. .......... Texas A & M College, College Station, Texas.
HILDRETH, A. C. .... Cheyenne Horticultural Station, Box 1250, Cheyenne, Wyo.
HILL, R. G., JR. .................. University of Maryland, College Park, Md.
HILLS, W. A. ........................ Louisiana Polytechnic Inst., Ruston, La.
HILTON, R. J. ............ University of Alberta, Edmunton, Alberta, Canada.
HINRICHS, HERMAN ............ Oklahoma A & M College, Stillwater, Okla.
HIROSHIGE, H. M. ........................ 1180 Alakea St., Honolulu, T. H.
HITCHCOCK, A. E. .................. Boyce Thompson Inst., Yonkers, N. Y.
HITZ, C. W. .......................... University of Delaware, Newark, Del.
HOADLEY, A. D. .................. Campbell Research Farm, Riverton, N. J.
HOAGLAND, D. R. .................. University of California, Berkeley, Calif.
HODGSON, R. W. ................ University of California, Los Angeles, Calif.
HOFFMAN, I. C. ...................... Ohio Experiment Sta., Wooster, Ohio.
HOFFMAN, J. C. ............ U. S. Vegetable Breeding Lab., Charleston, S. C.
HOFFMAN, M. B. .......................... Cornell University, Ithaca, N. Y.
HOFFMAN, R. M. ................ University of California, Red Bluff, Calif.
HOLIDAY, J. A. ...................... Orchard View Gardens, Eugene, Ore.
HOLLAND, F. L. ........................ P. O. Box 392, Winter Haven, Fla.
HOLLAR, V. E. .......................... James Seed Co., Rocky Ford, Colo.

Holley, W. D. .................. Colorado Experiment Sta., Ft. Collins, Colo.
Hope, Claude .......................... Apartado 18, Turrialba, Costa Rica.
Hopp, Richard ....................... University of Vermont, Burlington, Vt.
Hopperstead, S. L. .............. B. F. Goodrich Chem. Co., Cleveland, Ohio.
Horn, A. S. ............................ University of Idaho, Boise, Idaho.
Hornby, C. A. ......... Dominion Exp. Laboratory, Summerland, B. C., Canada.
*Hough, L. F. .................. Rutgers University, New Brunswick, N. J.
Hough, W. S. ............................ 523 Fairmont, Winchester, Va.
Houston, E. R. .................. Oklahoma A & M College, Stillwater, Okla.
Howard, F. L. ................ Rhode Island Experiment Sta., Kingston, R. I.
Howard, W. L. ...................... University of California, Davis, Calif.
Howell, M. J. ........................... Bishop College, Marshall, Texas.
Howlett, F. S. ...................... Ohio Experiment Sta., Wooster, Ohio.
Hoyle, B. J. .................................. Box 701, Tulelake, Calif.
Hrushka, H. W. .......... Rm. 1022, 641 Washington St., New York, N. Y.
Hubbard, L. V. ................................ Box 89, Hillsboro, Ore.
Hudson, N. D. ........................... Federal Building, Fresno, Calif.
Huelsen, W. A. ....................... University of Illinois, Urbana, Ill.
Huff, W. C. ........................... 50 W. Broad St., Columbus, Ohio.
Huffington, J. M. ..................... 600 DeBaugh Ave., Towson, Md.
Hughes, M. B. .................... Edisto Experiment Sta., Blackville, S. C.
Hull, J. W. ......................... 1221 N. W. 12, Oklahoma City, Okla.
Hunkle, V. H. .................... 797 N. Milwaukee St., Milwaukee, Wis.
Hunt, F. C. ........................... 421 N. Noyes Blvd., St. Joseph, Mo.
Hunter, H. A. ......................... 405 Magnolia Ave., Frederick, Md.
Hutchins, A. E. .................. University of Minnesota, St. Paul, Minn.
Hutchins, L. M. ................... Plant Industry Station, Beltsville, Md.
Hutton, F. V. ...... Dominion Experiment Sta., Prince George, B. C., Canada.
Hyser, R. A. ...................... 2922 Washburn Ave., Minneapolis, Minn.

Irving, Mrs. E. J. ............................ 4612 Sartoga, Omaha, Neb.
Isaac, E. E. ...................... Montana State College, Bozeman, Mont.
Isbit, Arthur ................. Michigan State College, East Lansing, Mich.
Ivanoff, S. S. .............. Mississippi Experiment Sta., State College, Miss.
Iverson, V. E. .................... University of Montana, Bozeman, Mont.
Iwakiri, B. T. ................. University of Maryland, College Park, Md.

Jacob, H. E. ......................... University of California, Davis, Calif.
Jacob, W. C. ............ L. I. Vegetable Research Farm, Riverhead, N. Y.
Jacobs, H. L. ........................... Davey Tree Expert Co., Kent, Ohio.
Janes, B. E. ........................ University of Florida, Gainesville, Fla.
Jenkins, J. M., Jr. ...... No. Car. Vegetable Research Lab., Wilmington, N. C.
Jenkins, W. F. ............... University of Maryland, College Park, Md.
Johannessen, G. A. ....................... Cornell University, Ithaca, N. Y.
John, C. A. ......................... H. J. Heinz Co., Bowling Green, Ohio.
Johnson, C. C. ............................ 117 Liberty St., New York, N. Y.
Johnson, H. A. ...................... P. O. Box 493, Santa Barbara, Calif.
Johnson, R. B. ............................ Experiment Station, Hope, Ark.
Johnson, W. A. .......................... 242 South Gay St., Auburn, Ala.
Johnson, W. B. ............... University of Massachusetts, Amherst, Mass.
Johnston, E. C. ......................... Chas. H. Lilly Co., Albany, Ore.
Johnston, J. C. .................... Citrus Experiment Sta., Riverside, Calif.
Johnston, Stanley .......... Michigan Experiment Sta., South Haven, Mich.
Johnstone, F. E., Jr. ............... Ohio State University, Columbus, Ohio.
Joley, L. E. .................................. Box 1040, Chico, Calif.
Jones, F. D. ........................... 2617 St. Davids Lane, Ardmore, Pa.
Jones, G. W. ............................... 801 98th Ave., Oakland, Calif.
Jones, H. A. ...................... Plant Industry Station, Beltsville, Md.
Jones, L. E. .......................... Oregon State College, Corvallis, Ore.
Jones, L. H. ................. University of Massachusetts, Amherst, Mass.
Jones, R. E. ................................ Box 167, Kennewick, Wash.
Jones, R. W. ................... University of California, Los Angeles, Calif.

Jones, S. E. .................. Texas Experiment Sta., College Station, Tex.
Jones, T. H. ...................... University of Tennessee, Knoxville, Tenn.
Jones, W. W. ............ California Citrus Experiment Sta., Riverside, Calif.
Jorgensen, Hans .................... Plant Industry Station, Beltsville, Md.
Judkins, W. P. ...................... Ohio Experiment Sta., Wooster, Ohio.
Jungerman, A. A. .............................. Box 1411, Modesto, Calif.

Kalin, E. W. ..................... Washington State College, Pullman, Wash.
Kalmar, A. F. ............................. P. O. Box 552, Riverside, Calif.
Kamemoto, Haruyuki ................... 107 Harvard Place, Ithaca, N. Y.
Kamp, J. R. .............................. University of Illinois, Urbana, Ill.
Karr, Chadwick ...................... 1224 S. 24th Avenue, Yakima, Wash.
Kasimatis, A. N. ............................ 2610 M St., Bakersfield, Calif.
Kattan, A. A. .................... University of Maryland, College Park, Md.
Kays, W. R. .................. Oklahoma Experiment Sta., Stillwater, Okla.
Keane, F. W. L. ...... Dominion Experiment Sta., Summerland, B. C., Canada.
Keen, R. A. ......................... Kansas State College, Manhattan, Kans.
Keener, R. L. ............................ University of Georgia, Athens, Ga.
Kelly, W. C. ............ U. S. Plant, Soil, and Nutrition Lab., Ithaca, N. Y.
Kelsall, A. .... Agricultural Experiment Sta., Kentville, Nova Scotia, Canada.
Kemper, C. R. ............ University of West Virginia, Morgantown, W. Va.
Kennard, W. C. .............. Pennsylvania State College, State College, Pa.
Kenworthy, A. L. .............. Michigan State College, East Lansing, Mich.
Kerr, W. L. ................ Forestry Nursery Sta., Sutherland, Sask., Canada.
Kessler, G. M. .................. Michigan State College, East Lansing, Mich.
Keswick, R. C. .............. California Packing Corp., Crystal City, Texas.
Keyes, C. G. ........................ University of Connecticut, Storrs, Conn.
Khan, F. R. .......... Tarnab Farm, Peshawar N. W. F. Province, Pakistan.
Khan, O. R. ...................... University of Minnesota, St. Paul, Minn.
Kiehart, Stephen .......................... Box 351, State College, Pa.
Kienholz, J. R. ................ U. S. Fruit Disease Lab., Hood River, Ore.
Kikuta, K. ........................................ Wainae, Oahu, Hawaii.
Kimball, M. H. ...................... 808 N. Spring St., Los Angeles, Calif.
Kimbrough, W. D. .............. Louisiana State University, University, La.
King, J. R. ................................ Brunswick Hotel, Boston, Mass.
King, Thomas H. ............... University of Minnesota, St. Paul, Minn.
King, L. J. .......................... 1086 North Broadway, Yonkers, N. Y.
Kinman, C. F. ...................... Plant Industry Station, Beltsville, Md.
Kiplinger, D. C. .................... Ohio State University, Columbus, Ohio.
Kitchen, E. M. ...................................... Beaver Dam, Wisc.
Klose, A. N. ............................ 3624 N. 62 St., Milwaukee, Wis.
Klotzbach, C. L. .................................. Box 55, Kendall, Fla.
Knott, J. E. ........................ University of California, Davis, Calif.
Koch, A. A. ............................ R. 2, Box 967B, Los Altos, Calif.
Koelling, A. C. ...................... Palmer Sanitorium, Springfield, Ill.
Kofranek, A. M. .......................... Cornell University, Ithaca, N. Y.
Kohl, H. C. ............................. Cornell University, Ithaca, N. Y.
Kohner, Mrs. Bertha E. .... 3212 Northampton St., N. W., Washington, D. C.
Kral, Milton E. ..................... 608 Erie St. S. E., Minneapolis, Minn.
Kramer, Amihud ............... University of Maryland, College Park, Md.
Krantz, F. A. ...................... University of Minnesota, St. Paul, Minn.
Kraus, E. J. ........................ Oregon State College, Corvallis, Oregon.
Kraus, J. E. ........................ Idaho Experiment Sta., Moscow, Idaho.
Krezdorn, A. H. ............ Texas A & M College, College Station, Texas.
Krimbas, B. D. .................... 65 Aghion, Meletion Str., Athens, Greece.
Krishnamurthi, S. ............ Michigan State College, East Lansing, Mich.
Krochmal, Arnold .......... New Mexico State College, State College, N. M.
Krone, P. R. .................... Michigan State College, East Lansing, Mich.
Kunkel, Robert ............... Colorado A & M College, Ft. Collins, Colo.
Kushman, L. J. .................... Plant Industry Station, Beltsville, Md.
Kvaale, Erling .... Statens Forsoksgard Njos, Hermansverk, Sogn, Norway.
Kwong, Shue Shan ............... Kansas State College, Manhattan, Kans.

LACHMAN, W. H...............University of Massachusetts, Amherst, Mass.
LAMB, R. C..................New York State Experiment Sta., Geneva, N. Y.
LAMBETH, V. N.. .....................University of Missouri, Columbia, Mo.
LANA, E. P...............................Iowa State College, Ames, Iowa.
LANDON, R. H.....................University of Minnesota, St. Paul, Minn.
LANGE, A. H..........................University of Arizona, Tucson, Ariz.
LANGER, C. A................Michigan State College, East Lansing, Mich.
LARGE, J. R..........................25 Pecan Laboratories, Monticello, Fla.
LARSEN, E. J..........................University of Idaho, Moscow, Idaho.
LARSON, RUSSELL..............Pennsylvania State College, State College, Pa.
LATIMER, L. P.................University of New Hampshire, Durham, N. H.
LAUMEISTER, L. T.........................R. 2, Box 20A40, Los Gatos, Calif.
LAURI, ALEX........................Ohio State University, Columbus, Ohio.
LAVOIE, J. H.........................Dept. of Agriculture, Quebec, Canada.
LAZARUK, W...............................1010 4th St., Brookings, S. Dak.
LEACH, WILL.......................Scranton Life Building, Scranton, Pa.
LECOMPTE, S. B., JR...............Rutgers University, New Brunswick, N. J.
LECRONE, FRED..................Oklahoma A & M College, Stillwater, Okla.
LEISER, A. T.....................Washington State College, Pullman, Wash.
LENZ, FRED..............................R. D. 1, Box 279, Homestead, Fla.
LEONARD, O. A.............Mississippi Experiment Sta., State College, Miss.
LEPORE, ARMANDO.................Libby, McNeill & Libby, Wyoming, Del.
LESLIE, E. H.............................Traver Road, Ann Arbor, Mich.
LESLIE, J. W......................Citrus Experiment Sta., Riverside, Calif.
LEVERING, S. R.........................................Ararat, Virginia.
LEWIS, F. H.........................Fruit Research Lab., Arendtsville, Pa.
LEWIS, M. T...................Pennsylvania State College, State College, Pa.
LILLELAND, OMUND....................University of California, Davis, Calif.
LILLEY, I. W...................................Box 208, Placerville, Calif.
LINDE, J. E., JR..............Pennsylvania State College, State College, Pa.
LINDNER, R. C...........................1009 Vassar St., Wenatchee, Wash.
LINK, C. B......................University of Maryland, College Park, Md.
*LINVILL, L. W.......................................R. 2, Media, Pa.
LITTLEFIELD, LYLE ........................University of Maine, Orono, Me.
LLOYD, J. W......................432 S. Grand Oaks Ave., Pasadena, Calif.
LOBENSTEIN, C. W...................Kansas State College, Manhattan, Kans.
LOCKE, L. F.....U. S. Southern Great Plains Field Station, Woodward, Okla.
LOCKHART, J. A..................M.S.C. Trailers A-6, East Lansing, Mich.
LOEHWING, W. F.........................University of Iowa, Iowa City, Ia.
LOGAN, JOHN..................Stark Brothers Nurseries Co., Louisiana, Mo.
LOMMEL, W. E..........................Purdue University, Lafayette, Ind.
LONG, D. D............................20 N. Wacker Drive, Chicago, Ill.
LONG, E. M.............................Apt. 176, Torreon, Coah, Mexico.
LONGLEY, L. E....................University of Minnesota, St. Paul, Minn.
LOOMIS, N. H................U. S. Horticultural Field Sta., Meridian, Miss.
LOOMIS, W. E.............................Iowa State College, Ames, Iowa.
LORENZ, O. A.......................University of California, Davis, Calif.
LORZ, A. P.......................Florida Experiment Sta., Gainesville, Fla.
LOTT, R. V............................University of Illinois, Urbana, Ill.
LOTT, W. L................North Carolina Experiment Sta., Raleigh, N. C.
LOUSTALOT, A. J.........U.S.D.A. Federal Experiment Sta,. Mayaguez, P. R.
LOWMAN, M. S.......................Plant Industry Station, Beltsville, Md.
LUCAS, E. H..................Michigan State College, East Lansing, Mich.
LUCE, W. A...............................2311 Barge Ave., Yakima, Wash.
LUMSDEN, D. V........................8 Park View Rd., Chevy Chase, Md.
LUND, R. H...................................R. 2, Wenatchee, Wash.
LUTZ, J. M..................U. S. Horticultural Field Sta., Meridian, Miss.
LYON, A. V......Commonwealth Research Sta., Merbein, Victoria, Aústralia.
LYON, C. B.....................Hawaiian Pineapple Co., Honolulu, T. H.

MACDANIELS, L. H........................Cornell University, Ithaca, N. Y.
MACGILLIVRAY, J. H..................University of California, Davis, Calif.

MacKellar, L. D....................California Packing Corp., Portland, Ore.
McCartney, J. S..................129 Sixth Avenue S. E., Minneapolis, Minn.
McCollam, M. E...............314 First National Bank Bldg., San Jose, Calif.
McCollum, J. P..........................University of Illinois, Urbana, Ill.
McCombs, C. L.....................Ohio State University, Columbus, Ohio.
McCrory, S. A.................South Dakota State College, Brookings, S. D.
McDaniel, J. C.....................403 State Office Bldg., Nashville, Tenn.
McElroy, Miss Leona A......................Fortin Road, Kingston, R. I.
McElwee, E. W.............Mississippi State College, State College, Miss.
McHatton, T. H........................University of Georgia, Athens, Ga.
McKay, John W....................Plant Industry Station, Beltsville, Md.
McKillop, J. E.......Dominion Experiment Sta., Morden, Manitoba, Canada.
McLarty, H. R...Dominion Lab. Plant Pathology, Summerland, B. C., Canada.
McLaughlin, G. A...........Merrimack Farmers' Exchange, Concord, N. H.
McLaughlin, Harland, Jr......................416 Adams, Macomb, Ill.
McLean, J. G....................Branch Experiment Sta., Aberdeen, Idaho.
McLellan, R. I.........................E. W. McLellan Co., Colma, Calif.
McMahan, J. E.......University of Tennessee Junior College, Martin, Tenn.
McMunn, R. L.........................University of Illinois, Urbana, Ill.
McNamee, R. W.............437 MacCorkle Ave., South Charleston, W. Va.

Mack, W. B................Pennsylvania State College, State College, Pa.
Magistad, O. C.........................2721 Puuhonua St., Honolulu, T. H.
Magness, J. R.......................Plant Industry Station, Beltsville, Md.
Magoon, C. A.........................4308 Queensberry Rd., Riverdale, Md.
Magruder, Roy..........U. S. Department of Agriculture, Washington, D. C.
Mahoney, C. H................National Canners Assn., Washington, D. C.
Maisonneuve, Gerard de......College of Agr. Ste-Martine, Quebec, Canada.
Maksoud, M. A......................University of California, Davis, Calif.
Mann, L. K........................University of California, Davis, Calif.
Manville, Samuel......................601 St. Augustine, Bogalusa, La.
Marks, R. T...Philippine Packing Corp., Bugo Misamis Oriental, Philippines.
Marsh, R. S..............University of West Virginia, Morgantown, W. Va.
Marshall, R. E..............Michigan State College, East Lansing, Mich.
Marth, P. C........................Plant Industry Station, Beltsville, Md.
Martin, D.........Division of Plant Industry, Hobart, Tasmania, Australia.
Martin, J. A., Jr............South Carolina Experiment Sta., Clemson, S. C.
Martin, W. E.........................239 Giannini Hall, Berkeley, Calif.
Mason, R. H..................South Carolina State College, Clemson, S. C.
Mather, T. H................506 Marine Bldg., Vancouver, B. C., Canada.
Mathews, E. L..........................................Plymouth, Fla.
Mathisen, S. S.............9035A Watertown Plank Rd., Milwaukee, Wis.
Matkin, O. A...................................Box 308, Orange, Calif.
Mattson, Harold...............North Dakota State College, Fargo, N. D.
Mattus, G. E.........................Cornell University, Ithaca, N. Y.
Maxon, Marcus..........South Dakota Experiment Sta., Brookings, S. D.
Maxwell, N. P..................Texas Experiment Sta., Weslaco, Texas.
Meader, E. M.................University of New Hampshire, Durham, N. H.
Mayberry, B. D......................710 S. Logan Street, Lansing, Mich.
Mecartney, J. L............Pennsylvania State College, State College, Pa.
Mehlquist, G. A. L................2221 Tower Grove Ave., St. Louis, Mo.
Meister, R. T.........................1370 Ontario St., Cleveland, Ohio.
Mendall, S. C......................Taylor Wine Co., Hammondsport, N. Y.
Merchant, W. L..................Montana State College, Bozeman, Mont.
Merrill, Grant............................Box 877, Red Bluff, Calif.
Merrill, Samuel, Jr.............................Box 812, Bogalusa, La.
Metcalf, H. N....................Montana State College, Bozeman, Mont.
Michael, Ralph....................Texas Experiment Sta., Gilmer, Texas.
Michalski, L. A.............524 College Ave., Winnipeg, Manitoba, Canada.
Mikell, J. J.................Louisiana State University, Baton Rouge, La.
Miller, J. C.................Louisiana State University, Baton Rouge, La.
Miller, C. M..............................Box 230, Barberton, Ohio.

MILLER, V. J. . . . . University of Nebraska, Lincoln, Nebr.
MILLIKAN, D. F. . . . . University of Missouri, Columbia, Mo.
MILNE, C. G. . . . . Texas A & M College, College Station, Texas.
MINGES, P. A. . . . . University of California, Davis, Calif.
MINNUM, E. C. . . . . University of Connecticut, Storrs, Conn.
MITCHELL, A. E. . . . . Michigan State College, East Lansing, Mich.
MOLL, A. C. . . . . Ohio State University, Columbus, Ohio.
MOLTENO, E. B. F. . . . . Glen Elgin, Elgin C. P., South Africa.
MONOSMITH, R. O. . . . . Miss. State College, State College, Miss.
MOON, H. H. . . . . Plant Industry Station, Beltsville, Md.
MOORE, E. C. . . . . Room 404, U. S. Custom Bldg., San Diego, Calif.
MOORE, J. F. . . . . Western Wash. Experiment Sta., Puyallup, Wash.
MOORE, J. G. . . . . University of Wisconsin, Madison, Wis.
MOORE, P. W. . . . . Box 242, Azusa, Calif.
MOORE, R. C. . . . . Virginia Agr. Experiment Sta., Blacksburg, Va.
MOORE, W. D. . . . . 501 S. Andrews Ave., Ft. Lauderdale, Fla.
MORRIS, H. F. . . . . Texas Substation No. 2, R. 5, Tyler, Tex.
MORRIS, L. L. . . . . University of California, Davis, Calif.
MORRISON, A. K. . . . . Box 206, Bristol, Ind.
MORROW, E. B. . . . . North Carolina State College, Raleigh, N. C.
MORTENSEN, E. . . . . Texas Experiment Sta., No. 19, Winter Haven, Tex.
MOULTON, J. E. . . . . Michigan State College, East Lansing, Mich.
MOWRY, HAROLD . . . . . University of Florida, Gainesville, Fla.
MULHOLLAND, W. B. . . . . Monrovia Nursery Co., Monrovia, Calif.
MULLIGAN, B. O. . . . . University of Washington Arboretum, Seattle, Wash.
MULLISON, W. R. . . . . 2010 Ashman St., Midland, Mich.
MUNGER, H. M. . . . . Cornell University, Ithaca, N.Y.
MUNZ, P. A. . . . . Santa Ana Botanic Garden, Anaheim, Calif.
MURNEEK, A. E. . . . . University of Missouri, Columbia, Mo.
MURPHY, M. M., JR. . . . . Georgia Experiment Sta., Experiment, Ga.
MURPHY, PAUL . . . . . 8 Museum Road, Oxford, London, England.
MURWIN, H. F. . . . . Dominion Experiment Station, Harrow, Ontario, Canada.
MUSSER, A. M. . . . . South Carolina State College, Clemson, S. C.
MUSSER, J. L. . . . . Charter Seed Co., Twin Falls, Idaho.
MYHRE, ARTHUR . . . . . Western Wash. Experiment Sta., Puyallup, Wash.

NATIVIDADE, J. V. . . . . Estacao Agronomica Nacional, Alcobaca, Portugal.
NEAL, O. M., JR. . . . . University of West Virginia, Morgantown, W. Va.
NEARY, M. E. . . . . Nova Scotia Dept. Agr. & Marketing, Truro, N. S., Canada.
NELSON, ALVIN . . . . . 1531 Merchantville Ave., Pennsauken, N. J.
NETTLFS, V. F. . . . . University of Florida, Gainesville, Fla.
NEW, E. H. . . . . University of Idaho, Moscow, Idaho.
NEWCOMB, A. D. . . . . Foothill Laboratories, Box 277, Corona, Calif.
NEWCOMB, R. V. . . . . Box 144, Yuba City, Calif.
NICHOLS, H. E. . . . . Iowa State College, Ames, Iowa.
NIGHTINGALE, G. T. . . . . Box 3166, Honolulu, Hawaii.
NIXON, W. H. . . . . 98 Zabala Rd., Salinas, Calif.
NOLL, C. J. . . . . Pennsylvania State College, State College, Pa.
NORDLINGER, E. W. . . . . The Food Packer, Chicago, Ill.
NORTHRUP, R. C. . . . . Forest Ave., Middletown, R. I.
NUTTONSON, M. Y. . . . . Box 1022, Washington, D. C.
NYLUND, R. E. . . . . University of Minnesota, St. Paul, Minn.

OBERLE, GEORGE . . . . . Virginia Experiment Sta., Blacksburg, Va.
O'BRIEN, WASH R. . . . . 191 Michigan St., Benton Harbor, Mich.
OCHSE, J. J. . . . . 28 Salamanca Avenue, Coral Gables, Fla.
ODLAND, M. L. . . . . Pennsylvania State College, State College, Pa.
OEBKER, NORMAN . . . . . Detroit Road, Avon, Ohio.
OKKEN, C. R. . . . . Farmer Seed & Nursery Co., Faribault, Minn.
OLMO, H. P. . . . . University of California, Davis, Calif.
OLNEY, A. J. . . . . University of Kentucky, Lexington, Ky.
OPITZ, KARL . . . . . 819 Clark St., Visalia, Calif.

O'Reilly, H. J.............The Dalles Experimental Area, The Dalles, Ore.
*O'Rourke, F. L................Michigan State College, East Lansing, Mich.
Orr, H. P.......................Alabama Polytechnic Institute, Auburn, Ala.
Oesterle, E. C..........................Purdue University, Lafayette, Ind.
Osuna, Pedro.........................Box 607, Rio Piedras, Puerto Rico.
Overcash, J. P..............Mississippi State College, State College, Miss.
Overley, F. L................................Box 596, Wenatchee, Wash.
Owens, E. W.........................University of Idaho, Moscow, Idaho.

Page, E. M..............................Cornell Seed Co., St. Louis, Mo.
Palmer, Clinton.....................1013 Birch Rd., East Lansing, Mich.
Palmer, E. F.....Hort. Experiment Sta., Vineland Station, Ontario, Canada.
Palmer, R. G............................528 Mt. Hope Ave., Rochester, N. Y.
Palmer, R. W......................2871 Allerandro St., Los Angeles, Calif.
Palmiter, D. H.......New York State Experiment Sta., Poughkeepsie, N. Y.
Pancoast, H. M...............................Box 760, San Jose, Calif.
Parker, E. R.......University of California Experiment Sta., Riverside, Calif.
Parker, M. M....................................Box 2160, Norfolk, Va.
Parmenter, Read...........................................Suncook, N. H.
Patel, G. I..........................University of California, Davis, Calif.
Paur, Sherman..........New Mexico State College, State College, N. M.
Peacock, N. D....................University of Tennessee, Knoxville, Tenn.
Pearson, H. E....................................Box 38, LaVerne, Calif.
Pearson, O. H.... ....Eastern States Farmers Exch., West Springfield, Mass.
Pelton, W. C....................University of Tennessee, Knoxville, Tenn.
Peng-Fi, Li.................Pennsylvania State College, State College, Pa.
Pentzer, W. T...........U. S. Horticultural Field Station, R. 3, Fresno, Calif.
Perlmutter, Frank..U. S. Dept. of Agriculture, 209 River St., Hoboken, N. J.
Perry, B. A......................Texas Substation 19, Winter Haven, Texas.
Perry, V. G..............................Graves Apt. 24–A, Auburn, Ala.
Peterson, C. E........................Iowa Experiment Sta., Ames, Iowa.
Peterson, L. E................Muscatine Island Field Sta., Fruitland, Iowa.
Petrucci, V. E.......................Fresno State College, Fresno, Calif.
Pfahl, P. B................Pennsylvania State College, State College, Pa.
Pfeffer, B. W............................801 S. Main St., Borger, Texas.
Pickett, A. D.....Entomological Laboratory, Annapolis Royal, N. S., Canada.
Pickett, B. S.........................University of Georgia, Athens, Ga.
Pickett, B. S............Ministry of National Economy, Damascus, Syria
Pickett, W. F....................Kansas State College, Manhattan, Kans.
Pieniazek, S. A.....Inst. of Pomology, Osado Palocowa, Skierniewice, Poland.
Piersma, S. F.......................California Packing Corp., Rochelle, Ill.
Piringer, A. A., Jr..............University of Maryland, College Park, Md.
Poesch, G. H.........................1741 Cardiff Road, Columbus, Ohio.
Pollack, B. L................Pennsylvania State College, State College, Pa.
Poole, C. F...............................P. O. Box 18, Honolulu, T. H.
Porter, A. J..............................Parkside, Saskatchewan, Canada.
Porter, A. M.........................22 Manor Circle, Takoma Park, Md.
Porter, D. R.............................44 College Park, Davis, Calif.
Post, Kenneth........................Cornell University, Ithaca, N. Y.
Potter, G. F....................................Box 812, Bogalusa, La.
Powers, LeRoy............................Box 1250, Cheyenne, Wyo.
Pratt, A. N......................................Box 1202, Roanoke, Va.
Pratt, H. K.........................University of California, Davis, Calif.
Price, Hazen R......................R. 2, Amherstburg, Ontario, Canada.
Pridham, A. M. S........................Cornell University, Ithaca, N. Y.
Prince, V. E........................7505 Hopkins Ave., College Park, Md.
Pringle, R..................AMIK–TTD, APO 235, San Francisco, Calif.
Proebsting, E. L....................University of California, Davis, Calif.
Prushek, E.............................................R. 3, Niles, Mich.
Pryor, D. E..........................1713 S. California, Monrovia, Calif.
Pyle, Robert.............................................West Grove, Pa.

RAGLAND, C. H. . . . . . . . . . . . . . . Mississippi State College, State College, Miss.
RAHMLOW, H. J. . . . . . . . . . . . . . . . . 424 University Farm Place, Madison, Wis.
RAHN, E. M. . . . . . . . . . . . . . . . . . . . . . . . . University of Delaware, Newark, Del.
RAIRDEN, R. E. . . . . . . . . . . . . . . . . . . . . . . 306-1 F.P.H.A., West Lafayette, Ind.
RALEIGH, G. J. . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
RANDALL, T. E. . . . . . . . . . . . . . . . . . Washington State College, Pullman, Wash.
RANDHAWA, G. S. . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
RANDOLPH, U. A. . . . . . . . . . . . . . . . . . . Texas Experiment Sta., Montague, Texas.
RATHMELL, J. K., JR. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Greenville, Dela.
REECE, P. C. . . . . . . . . . . . . . . . . . . . . . . . . . . 415 N. Parramore St., Orlando, Fla.
REED, H. J. . . . . . . . . . . . . . . Purdue University Experiment Sta., Lafayette, Ind.
REED, H. M. . . . . . . . . . . . . . . . . . . . . . Florida Experiment Sta., Gainesville, Fla.
REEVE, ELDROW . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 215, Chicago, Ill.
REEVES, E. L. . . . . . . . . . . . . U. S. Dept. Agriculture, Box 99, Wenatchee, Wash.
REHDER, ALFRED . . . . . . . . . . . . . . . . . . . . Arnold Arboretum, Jamaica Plain, Mass.
REIMER, C. A. . . . . . . . . . . . . . . . . . . . . . . . . 510 Maple Street, South Haven, Mich.
REIMER, F. C. . . . . . . . . . . . . Southern Oregon Experiment Sta., Medford, Ore.
REITER, VICTOR . . . . . . . . . . . . . . . . . . . . . . 1195 Stanyan St., San Francisco, Calif.
REITH, W. A. . . . . . . . . . . . . . . . . . . . . University of Maryland, College Park, Md.
REUTHER, WALTER . . . . . . . . . . . . . . . . . . . . 415 N. Parramore St., Orlando, Fla.
REYNARD, G. B. . . . . . . . . . . . . . . . . . . . . . . . . Campbell Soup Co., Riverton, N. J.
REYNOLDS, H. W. . . . . . . . . . . . . . . . . . . . . . . . U. S. Field Station, Sacaton, Ariz.
RICHARDS, DAVID . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Sturgis, S. Dak.
RICHARDSON, H. B. . . . . . . . . . . . . . . . . . . . . . 3864 Ramona Dr., Riverside, Calif.
RICK, C. M., JR. . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
RIDGWAY, H. W. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Mickleton, N. J.
RILEY, H. K. . . . . . . . . . . . . . . . . . . . Southwestern Louisiana Inst., Lafayette, La.
RISLEY, E. B. . . . . . . . . . . . . . . . . University of New Hampshire, Durham, N. H.
RIZZI, A. D. . . . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
ROBBINS, W. R. . . . . . . . . . . New Jersey Experiment Sta., New Brunswick, N. J.
ROBERTS, A. N. . . . . . . . . . . . . . . . . . . . . . . . . Oregon State College, Corvallis, Ore.
ROBERTS, EDITH A. . . . . . . . . . . . . . . . . . . . . . . . . . 17 Dearborn St., Salem, Mass.
ROBERTS, J. W. . . . . . . . . . . . . . . . . . . . . . . 116 D, Park Ave. S., Winter Park, Fla.
ROBERTS, O. C. . . . . . . . . . . . . . . . . . . University of Massachusetts, Amherst, Mass.
ROBERTS, R. H. . . . . . . . . . . . . . . . . . . . . University of Wisconsin, Madison, Wis.
ROBERTSON, W. H. . . . . . . . . . . . . Dept. of Agriculture, Victoria, B. C., Canada.
RODNEY, D. R. . . . . . . . . . . . . . . New York State Experiment Sta., Geneva, N. Y.
ROESSLER, E. B. . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
ROEVER, W. E. . . . . . . . . . . . West Tennessee Experiment Sta., Jackson, Tenn.
ROGERS, B. L. . . . . . . . . . . . . . . . . . . . . University of Maryland, College Park, Md.
ROGERS, W. S. . . . . . . . . . . . . . . . . East Malling Research Station, Kent, England.
ROLLINS, H. A. . . . . . . . . . . . . . . . . . . . University of Connecticut, Storrs, Conn.
ROLLO, LORD . . . . . . . . . . . . . . . . . . . . . Pitcairns, Dunning, Perthshire, Scotland.
ROMBERG, L. D. . . . . . . . . U. S. Pecan Field Sta., Box 589, Brownwood, Texas.
ROMSHE, F. A. . . . . . . . . . . . . . . . . . . Oklahoma A & M College, Stillwater, Okla.
ROQUETA, R. S. . . . . . . . . . . . . . . Antiguo Hospital de Sta., Maria, Lerida, Spain.
ROSE, S. B. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2030 Main St., Glastonbury, Conn.
ROSS, EDWARD . . . . . . . . . . . . . . . . . . Washington State College, Pullman, Wash.
ROTOR, GAVINO . . . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
ROUNDS, M. B. . . . . . . . . . . . . . . . . . . . . . . 240 E. Philadelphia St., Whittier, Calif.
RUSSELL, C. E. . . . . . . . . . . . . . . . Michigan State College, East Lansing, Mich.
RYALL, A. L. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 1425, Harlingen, Tex.
RYGG, G. L. . . . . . . . . . . . . . . . . . U. S. Hort. Field Lab., Box 700, Pomona, Calif.

SARTORI, ELVINO . . . . . . . . . . Instituto de Fruticultura, Buenos Aires, Argentina.
SAVAGE, E. F. . . . . . . . . . . . . . . . . . . . Georgia Experiment Sta., Experiment, Ga.
SAX, KARL . . . . . . . . . . . . . . . . . . . . . . . . Arnold Arboretum, Jamaica Plains, Mass.
SAYRE, C. B. . . . . . . . . . . . . . . . New York State Experiment Sta., Geneva, N. Y.
SCHELL, C. E. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4 Haslett Place, Newark, Del.
SCHERMERHORN, L. G. . . . . New Jersey Experiment Sta., New Brunswick, N. J.
SCHMIDT, ROBT. . . . . . . . . . . . . . . . . North Carolina State College, Raleigh, N. C.
SCHOONOVER, W. R. . . . . . . . . . . . . . . . University of California, Berkeley, Calif.

Schrader, A. L.................University of Maryland, College Park, Md.
Schroeder, C. A.................University of California, Los Angeles, Calif.
Schroeder, R. A....................University of Missouri, Columbia, Mo.
Schubert, O. E..........................University of Illinois, Urbana, Ill.
Schultz, E. W.................Texas A & M College, College Station, Tex.
Schultz, J. H.......................State College Station, Fargo, N. D.
Schwalm, H. W.................. 2827 S. Baldwin Ave., Temple City, Calif.
Schwartze, D. C.........Western Wash. Experiment Sta., Puyallup, Wash.
Scott, E. W...........................Joseph Harris Co, Rochester, N. Y.
Scott, L. B.......................Montgomery Bldg., Spartanburg, S. C.
Scott, D. H.......................Plant Industry Station, Beltsville, Md.
Scott, G. W.......................Associated Seed Growers, Milpitas, Calif.
Scott, L. E....................University of Maryland, College Park, Md.
Scudder, W. T............................Cornell University, Ithaca, N. Y.
Seaver, H. B...................12 Whitehouse Ave., Poughkeepsie, N. Y.
Seeley, J. G.............................Cornell University, Ithaca, N. Y.
Sefick, H. J.................Clemson Agricultural College, Clemson, S. C.
Serr, E. F...........................University of California, Davis, Calif.
Shalucha, Barbara, Miss..........Indiana University, Bloomington, Ind.
Shanks, J. B....................University of Maryland, College Park, Md.
Sharpe, R. H......................807 S. W. 6th Terrace, Gainesville, Fla.
Sharvelle, Eric.........................Purdue University, Lafayette, Ind.
Shaulis, N. J...............New York State Experiment Sta., Geneva, N. Y.
*Shaw, J. K....................University of Massachusetts, Amherst, Mass.
Shifriss, Oved.........................Fordhook Farms, Doylestown, Pa.
Shoemaker, J. S.....Ontario Agricultural College, Guelph, Ontario, Canada.
Showalter, R. K.................Florida Experiment Sta., Gainesville, Fla.
Shun-Chan, Ng...................1454 Taylor St., San Francisco, Calif.
Sidwell, A. P.................................Maunaloa, Molokai, T. H.
Siegelman, H. W.....Monrovia Nursery Co., P. O. Box 196, Monrovia, Calif.
Simons, R. K..................Michigan State College, East Lansing, Mich.
Simpson, R. C......................................R. 1, Vincennes, Ind.
Sinclair, W. B....................3649 Rosewood Place, Riverside, Calif.
Singh, Gian.........................1607 Neil Avenue, Columbus, Ohio.
Singh, Lal..........................Jullundur City, East Punjab, India.
Singletary, B. H.............Louisiana State University, Baton Rouge, La.
Singletary, C. C.......................Purdue University, Lafayette, Ind.
Sites, J. W......................Citrus Experiment Sta., Lake Alfred, Fla.
Sitton, B. G........................U. S. Tung Laboratory, Bogalusa, La.
Skinner, H. T....................The Morris Arboretum, Chesterhill, Pa.
Skok, John.............................University of Illinois, Urbana, Ill.
Slate, G. L................New York State Experiment Sta., Geneva, N. Y.
Smith, B. C...........................Cornell University, Ithaca, N. Y.
Smith, C. L..................U. S. Pecan Field Station, Brownwood, Tex.
Smith, Edwin..........U. S. Department of Agriculture, Wenatchee, Wash.
Smith, H. J................................Box 1449, State College, Miss.
Smith, J. A.......................1476 Water St., Kelewna, B. C., Canada.
Smith, Ora............................Cornell University, Ithaca, N. Y.
Smith, P. F........................415 N. Parramore St., Orlando, Fla.
Smith, P. G.........................University of California, Davis, Calif.
Smith, W. B...........................3 N. Robert Blvd., Dayton, Ohio.
Smith, W. W.................University of New Hampshire, Durham, N. H.
Smock, R. M...........................Cornell University, Ithaca, N. Y.
Smoyer, K. M.......................511 E. Aliso St., Los Angeles, Calif.
Snyder, Elmer..................U. S. Experiment Vineyard, Fresno, Calif.
Snyder, G. B..................University of Massachusetts, Amherst, Mass.
Snyder, J. C....................Washington State College, Pullman, Wash.
Snyder, L. C......................University of Minnesota, St. Paul, Minn.
Snyder, W. E............................Cornell University, Ithaca, N. Y.
Sorensen, H. B.................Oklahoma A. & M. College, Stillwater, Okla.
Southwick, F. W..............University of Massachusetts, Amherst, Mass.
Southwick, Lawrence...............422 W. Carpenter St., Midland, Mich.

SOUTHWICK, R. W. ....................... 563 Murray St., Porterville, Calif.
*SPARKS, WALTER ....................... University of Idaho, Aberdeen, Idaho.
SPENCER, E. L. ................. Agricultural Experiment Sta., Bradenton, Fla.
SPIVEY, E. P. ................ Box 5372, State College Station, Raleigh, N. C.
STAIR, E. C. ............................. Purdue University, Lafayette, Ind.
STANKOVIC, DUSAN .............. University of Belgrade, Zemun, Yugoslavia.
STANFIELD, J. F. .......................... Miami University, Oxford, Ohio.
STARCHER, D. B. .................................. Box 811, Chelan, Wash.
STARK, A. L. ........................ 2225 S. Fifth East, Salt Lake City, Utah.
STARK, F. C., JR. ............... University of Maryland, College Park, Md.
STEELMAN, C. H., JR. .......................... Box 3-55, Princeton, N. J.
STEINBAUER, C. E. ..................... Plant Industry Station, Beltsville, Md.
STEPHENS, T. S. ............ Texas A. & M. College, College Station, Texas.
STEVENS, J. R. ................. J. T. Baker Chemical Co., Phillipsburg, N. J.
STEWART, H. L. ............................ Box 1323, State College, Miss.
STEWART, W. S. .................. University of California, Riverside, Calif.
STIER, R. L. ............................. Cornell University, Ithaca, N. Y.
STILLINGS, E. N. .................. University of Utah, Salt Lake City, Utah.
STOREY, W. B. .................... University of Hawaii, Honolulu, Hawaii.
STOUT, G. J. ......................... University of Florida, Gainesville, Fla.
*STOUTEMYER, V. T. ............ University of California, Los Angeles, Calif.
STOW, R. P. ...................... FPHA, 312-2 W. State St., Lafayette, Ind.
STRAND, A. B. ................................. Box 157, Dandridge, Tenn.
STRUCKMEYER, B. ESTHER .......... University of Wisconsin, Madison, Wis.
STUART, G. M. .................... College of Agriculture, Glasgow, Scotland.
STUART, N. W. ...................... Plant Industry Station, Beltsville, Md.
SUDDS, R. H. .............. University of West Virginia, Morgantown, W. Va.
SWARTLEY, J. C. ..................... 406 Bethlehem Pk., Philadelphia, Pa.
SWEETMAN, LEONARD ........... Las Animas Floral Co., Las Animas, Colo.
SWIM, H. C. ......................... Armstrong Nurseries, Ontario, Calif.
SWINGLE, C. F. .............. Peninsula Experiment Sta., Sturgeon Bay, Wis.
SWINGLE, H. D. .................. University of Tennessee, Knoxville, Tenn.
SYAMAL, N. B. .............. Bihar Agricultural College, Sabour, Bihar, India.
SYAMAL, N. B. ............................ P. O. Digha Patna, Bihar, India.

TAI, E. A. .............. Department of Agriculture, Hope, Jamaica, B. W. I.
TALBERT, T. J. ...................... University of Missouri, Columbia, Mo.
TAWSE, W. J. ............ 5659 Terrebourne Ave., Montreal, Quebec, Canada.
TAYLOR, R. H. ............................ 1400–10th St., Sacramento, Calif.
TEAGUE, C. P. ............................ 309 Rimpau Ave., Corona, Calif.
TEMPER, C. R. ............ University of West Virginia, Morgantown, W. Va.
TESKE, A. H. .................. Virginia A. & M. College, Blacksburg, Va.
TEZIER, T. F. .............. 27 Avenue Gambetta, Valence-sur-Rhone, France.
THOMAS, FLORENCE ................. Marshall College, Huntington, W. Va.
THOMAS, F. B. .............. Pennsylvania State College, State College, Pa.
THOMAS, WALTER ............ Pennsylvania State College, State College, Pa.
THOMPSON, A. E. ....................... Cornell University, Ithaca, N. Y.
THOMPSON, A. H. ...................... U. S. Field Lab., Wenatchee, Wash.
THOMPSON, H. C. ....................... Cornell University, Ithaca, N. Y.
THOMPSON, MILLER ................................ Box 136, Conyers, Ga.
THOMPSON, ROSS C. .... U. S. Department of Agriculture, Washington, D. C.
THORNILEY, J. M. ........................... 132 E. I Street, Ontario, Calif.
THORNTON, N. C. .............. Tela Railroad Co., La Lima, Honduras, C. A.
THORNTON, S. F. .................... F. S. Royster Guano Co., Norfolk, Va.
TING, S. V. ...................... Ohio State University, Columbus, Ohio.
TING, S. V., MRS. ................ Ohio State University, Columbus, Ohio.
TISCHER, R. G. ......................... Iowa State College, Ames, Iowa.
TITUS, J. S. ............................ Cornell University, Ithaca, N. Y.
TOOLE, E. H. ....................... Plant Industry Station, Beltsville, Md.
TOOLE, W. E. ........................... Purdue University, Lafayette, Ind.
TOWNSEND, P. C. ........................................ Selbyville, Del.
TRAUB, H. P. ........................ Plant Industry Station, Beltsville, Md.

Trotter, Allen R. . . . . . . . . . . . . . . Associated Seed Growers, Robtown, Texas.
Tufts, W. P. . . . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
*Tukey, H. B. . . . . . . . . . . . . . . . . . . . Michigan State College, East Lansing, Mich.
Tukey, L. D. . . . . . . . . . . . . . . . . . . . . . . Ohio State University, Columbus, Ohio.
Tukey, R. B. . . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
Turnquist, O. C. . . . . . . . . . . . . . . . . University of Minnesota, St. Paul, Minn.
Turrell, F. M. . . . . . . . . . . . . . . . . . . . . University of California, Riverside, Calif.
Twigg, M. C. . . . . . . . . . . . . . . . . . . . . University of Maryland, College Park, Md.

Ulrich, Albert . . . . . . . . . . . . . . . . . . . . University of California, Berkeley, Calif.
Uota, M. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Cornell University, Ithaca, N. Y.
Upshall, W. H. . . Horticultural Exp. Sta., Vineland Station, Ontario, Canada.
Ure, C. R. . . . . . . . . . . . . . . . . . Experiment Station, Morden, Manitoba, Canada.
Uriu, Koyoto . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.

Van Amburg, Wallace . . . . . . . . . . . . . . 1818 W. Yakima Ave., Yakima, Wash.
Van Blaricom, L. O. . . . . . . . . South Carolina Experiment Sta., Clemson, S. C.
Vandermark, J. S. . . . . . . . . . . . . . . . . . . . . . . Purdue University, Lafayette, Ind.
Vanderwal, D. J. . . . . . . . . . . . . . . . . . . . . 444 Newton St., San Fernanco, Calif.
Van Doren, Archie . . . . . . . . . . . . . . . . . . . . . . . . . . 1817 B St., Pullman, Wash.
Van Horn, C. W. . . . . . . . . . . . . . . University Experiment Station, Yuma, Ariz.
Vannah, H. P. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 6, Brevard, N. C.
van Overbeek, J. . . . . . . . . . . . . . . . . . . Shell Oil Co. Agr. Lab., Modesto, Calif.
Vartiak, J. F. . . . . . . . . . . . . . . . . . . . . . . 4936 S. Winchester Ave., Chicago, Ill.
Veerhoff, Otto . . . . . . . . . . 1512 Connecticut Avenue, N. W., Washington, D. C.
Verner, Leif . . . . . . . . . . . . . . . . . . . . . . . . University of Idaho, Moscow, Idaho.
Vierheller, A. F. . . . . . . . . . . . . . . University of Maryland, College Park, Md.
Vines, H. M. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 106 C Street, Davis, Calif.
Vik, Jon . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . N.L.H., Vollebekk, Norway.
Vittum, M. T. . . . . . . . . . . . . . . New York State Experiment Sta., Geneva, N. Y.
Volz, E. C. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Iowa State College, Ames, Iowa.

Wade, B. L. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . University of Illinois, Urbana, Ill.
Wadleigh, C. H. . . . . . . . . . . . . . . U. S. Regional Salinity Lab., Riverside, Calif.
Walkden, H. . . . . . . . . . . The Raft, Derbyshire Rd., Sale, Manchester, England.
Walker, John . . . . . . . . . . . . . . . . . . . . . . . . Indian Head, Saskatchewan, Canada.
Walker, Lewis C. . . . . . . . . . . . . . . . . . . . . . . . . . R. 3, Box 67, Lampasas, Tex.
Walls, E. P. . . . . . . . . . . . . . . . . . . . . University of Maryland, College Park, Md.
Waltman, C. S. . . . . . . . . . . . . . . . . . . . University of Kentucky, Lexington, Ky.
Wanger, I. W. . . . . . . . . . . . . . . . . . . Citrus Experiment Sta., Lake Alfred, Fla.
Wann, F. B. . . . . . . . . . . . . . . . . . . . . . . . . . Utah Experiment Sta., Logan, Utah.
Waring, J. H. . . . . . . . . . . . . . . . . . . . . . . . . . . . University of Maine, Orono, Me.
Warmke, H. E. . . . . . . . . U. S. Agricultural Experiment Sta., Mayaguez, P. R.
Warne, L. G. G. . . . . . . . . . . . . . . University of Manchester, Manchester, England.
Warner, R. M. . . . . . . . . . . . . . . . . . . . . . California Fig Institute, Fresno, Calif.
Warren, G. F., Jr. . . . . . . . . . . . . . . . . . . . . . Purdue University, Lafayette, Ind.
Watson, D. P. . . . . . . . . . . . . . . . . Michigan State College, East Lansing, Mich.
Watson, R. R. . . . . . . . . . . . . . . . . . . . . . . . . . P. O. Box 129, Twin Falls, Idaho.
Watson, W. L. . . . . . . . . . . . . . . . . Michigan State College, East Lansing, Mich.
Watts, G. S. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Bellwood, Penn.
Watts, R. L. . . . . . . . . . . . . . . . Pennsylvania State College, State College, Pa.
Waugh, H. B. . . . . . . . . . . . . . . . . . . . . . . . . . Box 106, North Wilkesboro, N. C.
Way, R. D. . . . . . . . . . . . . . . New York State Experiment Sta., Geneva, N. Y.
Weaver, R. J. . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
Webb, R. E. . . . . . . . . . . . . . . . . . . . . . . . . . University Station, Baton Rouge, La.
Webbe, W. E. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Box 173, Barrington, Ill.
Weeks, W. D. . . . . . . . . . . . . . . . . . University of Massachusetts, Amherst, Mass
Weinard, E. F. . . . . . . . . . . . . . . . . . . . . . . . . . University of Illinois, Urbana, Ill.
Welch, J. E. . . . . . . . . . . . . . . . . . . . . . . . . University of California, Davis, Calif.
Wellensiek, S. J. . . Admin. van de Landborwhogoeshool, Wageningen, Holland.
Wellington, Richard . . . . . . New York State Experiment Sta., Geneva, N. Y.
Wellington, J. W. . . . . . . . Office of Experiment Stations, Washington, D. C.

WESTER, H. V. .................. National Capital Parks, Washington, D. C.
WESTER, R. E. ...................... Plant Industry Station, Beltsville, Md.
WESTOVER, K. C. ............... West Virginia University, Morgantown, W. Va.
WHALEY, W. G. ........................ University of Texas, Austin, Texas.
WHITAKER, T. W. ................................ Box 150, LaJolla, Calif.
WHITCOMB, W. D. ......................... 82 Blympton St., Waltham, Mass.
WHITE, D. G. ................ Pennsylvania State College, State College, Pa.
WHITEHOUSE, W. E. .................. Plant Industry Station, Beltsville, Md.
WIGGANS, C. C. ....................... University of Nebraska, Lincoln, Neb.
WIGGIN, W. W. ........................... Ohio University, Athens, Ohio.
WILCOX, A. N. ................... University of Minnesota, St. Paul, Minn.
WILCOX, J. C. .... Dominion Experiment Station, Summerland, B. C., Canada.
WILDE, J. E. .................................... Box 223, Blissfield, Mich.
WILLIAMS, C. F. ................ North Càrolina State College, Raleigh, N. C.
WILLIAMS, G. R. ............................. Substation 15, Weslaco, Texas.
WILLIAMS, H. H. ........................ 1311 S. Central, Los Angeles, Calif.
WILLIAMS, W. O. ................... University of California, Davis, Calif.
WILSON, GEORGE .............. Parliment Building, Toronto, Ontario, Canada.
WILSON, L. K. ....................... Southern Seedsman, San Antonio, Tex.
WINDHAM, S. L., JR. .... Truck Crops Experiment Sta., Crystal Springs, Miss.
WINGERT, J. B. ........................ 343 South Dearborn St., Chicago, Ill.
WINKLER, A. J. ........................ University of California, Davis, Calif.
WINSTON, J. R. ......................... 415 N. Parramore St., Orlando, Fla.
WINTER, F. L. ......................... 484 Whitney Ave., New Haven, Conn.
WINTERS, H. F. .................. Federal Experiment Sta., Mayaguez, P. R.
WINTER, J. D. ...................... University of Minnesota, St. Paul, Minn.
WINTER, S. W. .................. California Packing Corp., Sunnyvale, Calif.
WISCHHUSEN, J. F. .............. 15031 Shore Acres Drive, Cleveland, Ohio.
WITTWER, S. H. ................ Michigan State College, East Lansing, Mich.
WOLF, A. ...................... Everglade Experiment Sta., Belle Glade, Fla.
WOLFE, H. S. ........................ University of Florida, Gainesville, Fla.
WON, P. I. ....................... Extension Horticulturist, Suwon, Korea.
WONG, C. Y. ........................ Sun Yat Sen University, Canton, China.
WOOD, J. F. ............. 1002 Second National Bank Bldg., Houston, Texas.
WOOD, M. N. ................................. Box 1146, Sacramento, Calif.
WOODWARD, OTIS .......... Georgia Coastal Plain Experiment Sta., Tifton, Ga.
WOODBURY, C. G. ............... 1801 Hoban Road, N. W. Washington, D. C.
WOODBURY, G. W. ............ Parma Branch Experiment Sta., Parma, Idaho.
WOODFIN, VIRGIL ........ Texas Experiment Substation 16, Iowa Park, Texas.
WOODROFFE, F. B. .............. Better Homes and Gardens, Des Moines, Iowa.
WORK, PAUL ......................... 310 Elmwood Avenue, Ithaca, N. Y.
WRIGHT, R. C. ...................... Plant Industry Station, Beltsville, Md.
WYMAN, DONALD ................ Arnold Arboretum, Jamaica Plains, Mass.

YARBROUGH, D. B. .................... Fair & Sons Orchards, Nashville, Ark.
YARNELL, S. H. ................................ Box 844, Charleston, S. C.
YATES, H. O., JR. .. New Camden County Vocational School, Merchantville, N. J.
YEATMAN, J. N. ............................ Camp Detrick, Frederick, Md.
YOUNG, E. K. ........................ 2726 Greenwood Dr., Richmond, Calif.
YOUNG, R. S. .................. Michigan State College, East Lansing, Mich.

ZARGER, T. G. .......................................... T. V. A., Norris, Tenn.
ZIELINSKI, QUENTIN .................. Oregon State College, Corvallis, Ore.
ZIMMERMAN, F. S. ............... 641 Washington St., New York City, N. Y.
ZIMMERMAN, P. W. ............... Boyce Thompson Institute, Yonkers, N. Y.
ZUCKER, ISABEL ......................... 1708 Crooks Rd., Royal Oak, Mich.

## JUNIOR BRANCH MEMBERSHIPS

Clemson Agricultural College, Clemson, S. C.
Michigan State College, East Lansing, Mich.
Louisiana State University, Baton Rouge, La.
Purdue University, Lafayette, Ind.

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